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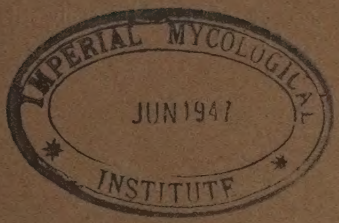

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MATHÉMATIQUES

SUR L'ABAISSEMENT DU DEGRÉ DES POLYNÔMES EN AFFINEURS*

Par J. DUBNOV et V. IVANOV

(Présenté par A. N. Kolmogoroff, de l'Académie, le 3. VIII. 1943)

1. Position du problème. Notations. L'équation de Hamilton—Cayley permet de transformer un polynôme à coefficients scalaires dépendant d'un affineur n-dimensionnel en un polynôme de la même nature et de degré au plus égal à $n-1$. Dans la présente Note nous posons et donnons la solution d'un problème analogue concernant l'abaissement du degré d'un polynôme qui dépend de plusieurs affineurs n-dimensionnels. Il est naturel de prendre pour point de départ «l'équation généralisée de Hamilton—Cayley» (1). Ainsi pour $n=2$ on trouve que chaque polynôme en affineurs peut être présenté sous la forme d'un polynôme de degré au plus égal à 2, si l'on tient compte de l'identité facile à établir:

$$2A_1A_2A_3=\{A_1\}A_2A_3+\{A_2\}A_1A_3+\{A_3\}A_2A_1+\{A_2A_3\}A_1+$$
$$+\{A_1,A_3\}A_2-\{A_1,A_2\}A_3-\{A_1,A_2A_3\}, \qquad (1)$$

où les A_i sont des affineurs à deux dimensions; les symboles en crochets désignent des scalaires dépendant de ces affineurs [les notations sont celles de l'article (1)]. Pour $n=3$ V. Ivanov a établi ** (par les moyens de l'algèbre moderne) qu'il est possible d'abaisser le degré pour un produit de six affineurs et qu'il est impossible d'avoir un tel abaissement, si le nombre des facteurs est plus petit; une expression explicite du type (1) est ici probablement très compliquée.

Si la forme P de degré h polylinéaire par rapport aux affineurs $A_1,\ldots, A_h$ (c'est-à-dire une combinaison linéaire à coefficients constants des produits de ces affineurs dont on a pris des permutations diverses) peut être transformée identiquement en une somme de produits dont chacun est formé de $h-1$ affineurs A_i au plus et d'un facteur scalaire (dépendant des A_i), nous dirons que la forme P «est réductible par rapport à $A_1,\ldots, A_h$» et nous écrirons

$$P\equiv 0;$$

par exemple, il suit de (1) que le produit $A_1A_2A_3$ est réductible. Il faut souligner que la réductibilité n'est pas une propriété du système des affineurs A_i fixes,

* On entend ici par affineur un opérateur linéaire qui fait correspondre à chaque vecteur de l'espace affin un vecteur du même espace. Si dans ce dernier on a choisi une base, on peut au lieu de considérer les affineurs parler de matrices carrées.

** Dans sa thèse de candidat, «Certains problèmes de la théorie des polynômes en matrices», 1942.

mais une propriété de la forme P considérée comme polynôme qui dépend de h affineurs (indéterminés). La relation $P \equiv Q$ (que l'on doit lire: P est congruent à Q), où P et Q sont des formes polylinéaires par rapport à un même système d'affineurs, signifie que l'on a $P - Q \equiv 0$.

En substituant dans une forme réductible au lieu de l'affineur A_i une forme polylinéaire par rapport aux affineurs $A_{i1}, \ldots, A_{ik}$, nous aurons encore une forme réductible (par rapport à $A_1 \ldots, A_{i-1}, A_{i1}, \ldots, A_{ik}, A_{i+1}, \ldots A_h$). Le symbole

$$\underset{i_1 \ldots, i_r}{S} P$$

désignera la somme des $r!$ membres que l'on obtient à partir de la forme polylinéaire P donnée; en faisant toutes les permutations des affineurs $A_{i_1}; \ldots; A_{i_r}$; l'opération S sera nommée «symétrisation» suivant les affineurs $A_{i_1}; \ldots; A_{i_r}$. Si dans le produit de plusieurs affineurs la symétrisation est effectuée suivant s facteurs consecutifs; on parlera de symétrisation «le long d'un segment de longueur s» en indiquant; s'il est nécessaire, le facteur qui est à gauche (ou à droite) de tous les autres. Il suit de l'équation généralisée de Hamilton—Cayley dont nous avons déjà parlé que dans l'espace à n dimensions un produit symétrisé de n affineurs est réductible:

$$\underset{1, \ldots, n}{S} A_1 \ldots A_n \equiv 0. \tag{2}$$

Notre problème est de trouver pour chaque n un nombre $N(n)$ de facteurs tel que le produit (non symétrisé) $A_1 \ldots A_N$ est réductible. Remarquons que dans la suite au lieu de considérer les affineurs et les facteurs scalaires on peut parler d'éléments d'un anneau arbitraire vérifiant la condition (2), et d'opérateurs distributifs par rapport à l'addition et associatifs par rapport à la multiplication.

2. Théorème fondamental. Lemme. *Si un produit d'affineurs devient réductible après être symétrisé le long d'un segment de longueur* $s\,(>1)$

$$\underset{1, \ldots, s}{S} \ldots A_1 \ldots A_s \ldots \equiv 0, \tag{3}$$

alors sera aussi réductible le produit que l'on obtient du précédent en remplaçant ce segment par un autre de longueur $2s-1$, *deux fois symétrisé: par rapport aux* $s-1$ *premiers et aux* $s-1$ *ses derniers facteurs:*

$$\underset{1, \ldots, s-1}{S} \underset{s+1, \ldots 2s-1}{S} \ldots B_1 \ldots B_{s-1} B_s B_{s+1} \ldots B_{2s-1} \ldots \equiv 0. \tag{4}$$

Démonstration. Convenons de définir dans la suite le symbole tel que

$$A_r \ldots A_t \ (r \text{ et } t \text{ étant des entiers; } t \geqslant r-1 \geqslant 0) \tag{5}$$

par la formule récurrente

$$A_r \ldots A_t = \begin{cases} I \text{ (affineur unitaire) pour } t = r-1 \\ A_r (A_{r+1} \ldots A_t) \text{ pour } t \geqslant r. \end{cases}$$

Ainsi

$$A_r \ldots A_r = A_r,$$

et pour $t > r$ le symbole (5) désigne, comme ordinairement, un produit d'affineurs écrits de gauche à droite (donc, multipliés de droite à gauche) sui-

vant l'ordre de croissance des indices de r à t. Considérons la somme double

$$\sum_{i=1}^{s}\sum_{k=1}^{s} B_1 \dots B_{k-1} \cdot B_s B_{s+1} \dots B_{s+i-1} \cdot B_k \dots B_{s-1} \cdot B_{s+i} \dots, B_{2s-1}. \quad (6)$$

En vertu de (3)

$$S_{1,\dots s-1} \sum_{k=1}^{s} B_1 \dots B_{k-1} C B_k \dots B_{s-1} \equiv 0 \text{ suivant } B_1, \dots, B_{s-1}, C; \quad (3')$$

donc pour chaque $i\,(1 \leqslant i \leqslant s)$

$$S_{1,\dots s-1} \sum_{k=1}^{s} B_1 \dots B_{k-1} \cdot B_s B_{s+1} \dots B_{s+i-1} \cdot B_k \dots B_{s-1} \equiv 0 \text{ suivant } B_1, \dots, B_{2s-1},$$

c'est-à-dire la somme (6) étant symétrisée suivant $B_1, \dots B_{s-1}$ devient $\equiv 0$. D'autre part, la somme (6) est égale à

$$\sum_{k=1}^{s-1}\Big(B_1 \dots B_{k-1} B_s \sum_{i=1}^{s} B_{s+1} \dots B_{s+i-1} \cdot B_k \dots B_{s-1} \cdot B_{s+i} \dots B_{2s-1}\Big) +$$

$$+ \sum_{i=1}^{s} B_1 \dots B_{s-1} B_s B_{s+1} \dots B_{s+i-1} \cdot B_s \dots B_{s-1} \cdot B_{s+i} \dots B_{2s-1}.$$

La symétrisation suivant $B_{s+1}, \dots, B_{2s-1}$ étant faite, le premier membre devient $\equiv 0$, car la somme $\sum_i$ qu'il contient est $\equiv 0$ en vertu de (3'), et le second (où le produit sous le signe $\sum_i$ ne dépend pas de i, parce que $B_s \dots B_{s-1} = I$) devient

$$s\, S_{s+1, \dots, 2s-1} B_1 \dots B_{2s-1}.$$

Donc, si la somme (6) est symétrisée deux fois ainsi qu'il a été indiqué dans (4), on obtiendra (4).

Théorème. *Si le nombre des facteurs N vérifie l'inégalité $N \geqslant 2^n - 1$, alors le produit des affineurs n-dimensionnels est réductible.*

Démonstration. En appliquant le lemme à (2), on obtient un produit formé de $2n-1$ facteurs, qui devient réductible quand on le symétrise le long de deux segments, chacun de longueur $n-1$ et séparés par un facteur intermédiaire. En appliquant plusieurs fois le lemme, on obtient les produits: formé de 4 segments symétrisés de longueur $n-2$ et de 3 facteurs intermédiaires, ..., formé de 2^k segments symétrisés de longueur $n-k$ et de 2^k-1 facteurs intermédiaires, donc contenant $2^k(n-k+1)-1$ facteurs. Pour $k=n-1$ les symétrisations disparaissent, et nous obtiendrons un produit réductible formé de 2^n-1 facteurs.

3. Possibilité d'un abaissement ultérieur. Dans le théorème précédent nous avons donné pour N une évaluation qui sûrement n'est pas la meilleure possible: ainsi pour $n=3$ le théorème donne $N \geqslant 7$ au lieu de $N \geqslant 6$ (voir le commencement de cette Note). Cette dernière évaluation peut aussi être obtenue par les méthodes de cette Note, ce que nous montrons dans la suite.

Pour abréger; nous écrirons dans la suite au lieu de $A_1, \dots, A_6$ simplement 1, ..., 6, et la symétrisation le long d'un segment sera désignée en prenant entre parenthèses les facteurs de ce segment. La congruence (2) prend alors la forme

$$(123) \equiv 0 \quad (7)$$

d'où

$$S^{13}\,123 \equiv -(12)\,3 - 1\,(23). \tag{8}$$

En vertu du lemme il suit de (7) que l'on a $(12)\,3\,(45) \equiv 0$; en appliquant le lemme encore une fois à l'un des segments extrêmes de symétrisation, on aura

$$(12)\,3456 \equiv 1234\,(56) \equiv 0. \tag{9}$$

La congruence (7) appliquée aux trois affineurs 123, 45, 6 donne:

$$123456 + 645123 + 451236 + 456123 + 123645 + 612345 \equiv 0. \tag{10}$$

En symétrisant suivant 4, 5 et ensuite encore une fois suivant 2, 3 et en tenant compte de (9) nous trouvons successivement:

$$123\,(45)\,6 + 6\,(45)\,123 \equiv 0, \tag{11}$$

$$1\,(23)\,(45)\,6 \equiv 0. \tag{12}$$

Il suit de (9) et (12) que l'on a:

$$(12)\,(34)\,56 \equiv (12)\,3\,(45)\,6 \equiv (12)\,34\,(56) \equiv$$
$$\equiv 1\,(23)\,(45)\,6 \equiv 1\,(23)\,4\,(56) \equiv 12\,(34)\,(56) \equiv 0.$$

Et comme la symétrisation suivant deux facteurs non-voisins peut être remplacée en vertu de (8) par des symétrisations le long de deux facteurs voisins, le produit 123456 devient réductible apres une symétrisation suivant deux couples quelconques sans éléments communs. En particulier, *le produit 123456, symétrisé le long d'un segment de longueur 2, change de signe (au sens $\equiv$) quand on fait la transposition de deux facteurs quelconques situés hors de ce segment.*

Appliquons maintenant (7) aux trois affineurs 12, 34, 56:

$$123456 + 125634 + 345612 + 341256 + 563412 + 561234 \equiv 0. \tag{13}$$

En symétrisant le long du segment 34 et en tenant compte de (9), nous aurons

$$12\,(34)\,56 + 56\,(34)\,12 \equiv 0,$$

et comme les permutations 1256 et 5612 sont de même parité, les deux membres sont mutuellement congruents, donc

$$12\,(34)\,56 \equiv 0. \tag{14}$$

En symétrisant maintenant (10) suivant 3, 5, en appliquant chaque fois (8) et en tenant compte de (9), (14), on obtient:

$$124\,(35\,6 + 4\,(35)\,126 + 412\,(35)\,6 + 4\,(35)\,612 + 612\,(35)\,4 \equiv 0.$$

En vertu de (11) les deux derniers membres doivent être rejetés, et $4\,(35)\,126$ peut être remplacé par $-126\,(35)\,4 \equiv 124\,(35)\,6$:

$$124\,(35)\,6 + 124\,(35)\,6 + 412\,(35)\,6 \equiv 0.$$

Et comme les permutations 1246 et 4126 sont de même parité, on a $124\,(35)\,6 \equiv 0$. En changeant les notations et comparant avec (11) nous trouvons:

$$123\,(45)\,6 \equiv 1\,(23)\,456 \equiv 0. \tag{15}$$

Les congruences (9), (14), (15) montrent que le produit 123456 «change de signe» quand on fait la transposition de deux facteurs voisins (donc, aussi quelconques). Et comme les permutations dans les six produits de la congruence (13) sont de même parité, ces produits sont mutuellement congruents, donc (pour $n = 3$) on a

$$123456 \equiv 0.$$

En s'appuyant sur ce résultat, on peut préciser le théorème précédent: *si $n \geqslant 3$, un produit contenant $N \geqslant 7 \cdot 2^{n-3} - 1$ facteurs est réductible.*

Le problème sur l'abaissement maximal du degré pour $n > 3$ reste à résoudre.

Université Lomonossoff, Moscou.
Institut des mines, Sverdlovsk.

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MATHEMATICS

HERMITE'S CRITERION FOR INTEGRAL FUNCTIONS OF EXPONENTIAL TYPE. II

By B. LEVIN

(Communicated by A. N. Kolmogoroff, Member of the Academy, 20. XII. 1942)

Let us prove that the conditions (B) and (D) of Theorem 1 of our note [1] are essential, i. e. that they are necessarily fulfilled for every function of exponential type, to which the Hermite criterion is applicable.

Theorem 1. *The conditions* (A) *and* (C) *of Theorem* 1 [1] *imply the conditions* (B) *and* (D).

Assume that the condition (D) does not hold. Then (13) and (17) imply [1]

$$F(z)=\frac{B}{A}e^{Kz}\psi(z) \qquad (K^2>0).$$

By Lemma 3 [1] the imaginary part of the infinite product does not change its sign in the upper semi-plane. For the sake of definitiveness we suppose that $k>0$ and

$$I\left[\frac{B}{A}\psi(z)\right]>0 \quad \text{for} \quad Iz>0.$$

It is evident that every segment $\frac{4n+1}{2k}\pi\leqslant y\leqslant\frac{4n+3}{2k}\pi$ contains a point, in which $\arg F(z)=2n\pi+\frac{3}{2}\pi$.

Evaluating the modulus of $F(z)$ within the angle $\eta\leqslant\arg z\leqslant\pi-\eta$, we shall have:

$$\ln|\psi(z)|=\sum_{-\infty}^{\infty}\ln\left|1-\frac{z\left(\frac{1}{b_k}-\frac{1}{a_k}\right)}{1-\frac{z}{a_k}}\right|<|z|\sum_{-\infty}^{\infty}\frac{1}{\left|1-\frac{z}{a_k}\right|}\left(\frac{1}{a_k}-\frac{1}{b_k}\right)<$$

$$<\frac{\delta(z)}{1-\delta}\sum_{|a_k|\leqslant\delta|z|}\left(\frac{1}{a_k}-\frac{1}{b_k}\right)+\frac{|z|}{\sin\eta}\sum_{|a_k|>\delta|z|}\left(\frac{1}{a_k}-\frac{1}{b_k}\right). \qquad (0<\delta<1)$$

Hence $|\psi(z)|<e^{\varepsilon|z|}$ for $|z|>R_\varepsilon$. Considering the inverse value, we shall have

$$e^{kx-\varepsilon|z|}<|F(z)|<e^{kx+\varepsilon|z|}. \qquad (1)$$

It follows from these inequalities that, for sufficiently large n, there exists a point z_0 on the curve $\arg F(z)=2n\pi+\frac{3\pi}{2}$, in which $|F(z_0)|=1$ and, consequently, $F(z_0)=-i$, $\overline{f}(z_0)=0$ and $f(\overline{z_0})=0$.

Thus, the function $f(z)$ possesses an infinity of roots in the lower semi-plane.

We see that the conditions (C) and (D) imply the condition (B). The theorem is proved.

Consider now a particular case*.

Theorem 2. *All roots of the function*

$$f(z)=P(z)+iQ(z)=\sum_{k=1}^{n}e^{i\lambda_k z}P_k(z) \qquad (\lambda_1<\lambda_2<\ldots<\lambda_n,$$

$$\lambda_n>-\lambda_1, P_k(z) \text{ are polynomials})$$

lie in the upper semi-plane if and only if the roots of the functions $P(z)$ *and* $Q(z)$ *are real, alternate, and the inequality* $Q'(x)P(x)-P'(x)Q(x)>0$ *is fulfilled in at least one point.*

Proof. The necessity follows from the asymptotic formulae

$$\left.\begin{aligned} |f(z)|&=e^{-\lambda_1 y}|a_0||z|^{P_1}\left[1+O\left(\frac{1}{|x|}\right)\right] \quad \text{for } \eta<\arg z<\pi-\eta \\ &\qquad (\eta>0, \quad y=Iz) \\ f(z)|&=e^{-\lambda_n y}|b_0||z|^{P_n}\left[1+O\left(\frac{1}{|x|}\right)\right] \quad \text{for } -\eta>\arg z>-\pi+\eta. \end{aligned}\right\} \tag{2}$$

where $a_0z^{P_1}$ and $b_0z^{P_n}$ are the highest terms of the polynomials.

It is evident that the condition (B) of Theorem 1 ([1]) is fulfilled under the conditions imposed on λ_1 and λ_n. To prove the sufficiency we use the asymptotic formulae

$$|P(z)|=|\alpha_0|e^{\Delta_1 y}|z|^{n_1}\left[1+O\left(\frac{1}{|z|}\right)\right]$$

$$|Q(z)|=|\beta_0|e^{\Delta_2 y}|z|^{n_2}\left[1+O\left(\frac{1}{|z|}\right)\right] \quad (\eta\leqslant\arg z\leqslant\pi-\eta) \ (\eta>0), \tag{3}$$

where Δ_1 and Δ_2 are the highest degrees in the functions $P(z)$ and $Q(z)$, $\alpha_0z^{n_1}$ and $\beta_0z^{n_2}$ are the highest terms in the polynomials, by which $e^{-i\Delta_1 z}$ and $e^{-i\Delta_2 z}$ are multiplied.

By the formulae (3) we have

$$\left|\frac{Q(z)}{P(z)}\right|=\left|\frac{b_0}{a_0}\right||z|^{n_2-n_1}e^{(\Delta_2-\Delta_1)y}\left[1+O\left(\frac{1}{|z|}\right)\right] \quad (\eta\leqslant\arg z\leqslant\pi-\eta). \tag{4}$$

On the other hand, we have

$$e^{kx-\varepsilon|z|}<\left|\frac{Q(z)}{P(z)}\right|<e^{kx+\varepsilon|z|}, \quad (\eta\leqslant\arg z\leqslant\pi-\eta), \tag{5}$$

$$\left(k=b-a+\sum_{-\infty}^{\infty}\left(\frac{1}{b_k}-\frac{1}{a_k}\right)\right)$$

for $|z|>R_\varepsilon$.

It is evident that the equalities (4) and (5) can be fulfilled simultaneously if

$$\Delta_1=\Delta_2 \quad \text{and} \quad K=0,$$

i. e. under the conditions (C) and (D) of Theorem 1 ([1]).

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20. XII. 1942.

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* For this particular case the proof of Lemma 2 ([1]) is considerably simplified.

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MATHÉMATIQUES

SUR LE DEGRÉ D'ARBITRAIRE DANS LE PROBLÈME D'EXISTENCE D'UN COUPLE DE CONGRUENCES ORTHOGONAL BILATÉRALEMENT STRATIFIABLE DONT LA CONGRUENCE DES PERPENDICULAIRES COMMUNES EST ISOTROPE

Par S. ROSSINSKI

(Présenté par A. N. Kolmogoroff, de l'Académie, le 27. VI. 1942)

Dans l'article (1) j'ai indiqué le cas d'un couple de congruences orthogonal bilatéralement stratifiable dont la congruence des perpendiculaires communes est isotrope. Dans le présent article l'auteur résume es résultats qu'il a obtenu en étudiant ce cas.

Le système (3) de Pfaff (2) qui détermine une congruence arbitraire de droites rapportée à un repère choisi peut dans le cas, où la congruence (i_3) est isotrope, être écrit sous la forme:

$$\left.\begin{array}{ll} \omega^1 = \beta\omega_2^3 & \\ \omega^2 = -\beta\omega_1^3 & \omega_l^l = 0, \\ \omega^3 = \xi\omega_1^3 & \omega_k^l = -\omega_l^k. \quad (k, l = 1, 2, 3) \\ \omega_1^2 = \rho\omega_1^3 + \sigma\omega_2^3 & \end{array}\right\} \qquad (1)$$

En posant dans les équations (4) (2) $\alpha = \mu = 0$, $\lambda = -\beta$ nous aurons les conditions pour la stratification bilatérale du couple (j_1), (j_2) dont (i_3) est la congruence isotrope des perpendiculaires communes. L'avant-dernière équation (4) (2) prend maintenant la forme $l\cos\varphi = 0$; dans le cas où $l = 0$ on a les couples non-orthogonaux qui ont été considérés par l'auteur dans un article précédent (1), et si $\cos\varphi = 0$, on a un couple orthogonal, et c'est précisément ce cas qui sera considéré dans la suite.

Si $\cos\varphi = 0$, la dernière équation (4) (2) donne

$$dl + \xi\omega_1^3 = Ada, \qquad (2)$$

où A est un certain paramètre nouveau. En introduisant les notations:

$$p = \omega_1^3\cos\theta + \omega_2^3\sin\theta, \qquad C = \rho\cos\theta + \sigma\sin\theta,$$
$$q = \omega_2^3\cos\theta - \omega_1^3\sin\theta, \qquad D = -\sigma\cos\theta + \rho\sin\theta,$$

nous pouvons écrire les autres équations (4) (²) dans la forme:

$$\left.\begin{aligned}
&(A-1)\,[da,\,p]+2a\,[d\theta,\,q]+2aC\,[\omega_1^3\omega_2^3]=0,\\
&(A+1)\,[da,\,q]+2a\,[d\theta,\,p]+2aD\,[\omega_1^3\omega_2^3]=0,\\
&(A+1)\,[da,\,(l-a)\,p-\beta q]+2a\,[d\theta,\,-(l+a)\,q-\beta p]-\\
&\qquad -2a\,\{(l+a)\,C+\beta D\}\,[\omega_1^3\omega_2^3]=0\\
&(A-1)\,[da,\,(l+a)\,q+\beta p]+2a\,[d\theta,\,\beta q-(l-a)\,p]-\\
&\qquad -2a\,\{(l-a)\,D-\beta C\}\,[\omega_1^3\omega_2^3]=0
\end{aligned}\right\} \qquad (3)$$

Le déterminant de ce système par rapport aux produits extérieurs $[da, p]$, $[da, q]$, $[d\theta, p]$, $[d\theta, q]$ est $\Delta = 4(lA-a)^2$, et pour $\Delta \neq 0$ il est facile à voir que le problème considéré n'admet pas de solution.

Dans le cas $\Delta = 0$ l'équation (2) prend la forme

$$dl+\xi\omega_1^3=\frac{ada}{l}, \qquad (4)$$

et les deux dernières équations du système (3) deviennent des conséquences des deux premières. La dérivation extérieure de l'équation (4) et l'application du lemme de M. Cartan au résultat obtenu donne

$$da=\tau\omega_1^3-\frac{2\beta l^2}{\xi a}\omega_2^3, \qquad (5)$$

où τ est un nouveau paramètre, et la dérivation extérieure de l'équation (5) donne

$$[d\tau\omega_1^3]+\left\{\tau\left[\rho-\frac{2\beta}{\xi}\left(2-\frac{l^2}{a^2}\right)\right]+\frac{4\beta l}{a}\left(1-\frac{l\sigma}{\xi}\right)\right\}[\omega_1^3\omega_2^3]=0. \qquad (6)$$

En portant (5) dans les équations (3) qui restent et en appliquant le lemme de M. Cartan, on trouve

$$d\theta=P\omega_1^3+Q\omega_2^3, \qquad (7)$$

où P et Q sont certaines fonctions de θ, a, l, ξ, β, ρ, σ, τ.

La dérivation extérieure de l'équation (7) conduit à une égalité de la forme

$$[d\tau\omega_2^3]+R\,[\omega_1^3\omega_2^3]=0, \qquad (8)$$

où R est une certaine fonction de nature très compliquée des paramètres que nous venons d'indiquer.

En appliquant le lemme de M. Cartan aux équations (6) et (8) nous trouvons

$$d\tau=\tau_1\omega_1^3+\tau_2\omega_2^3, \qquad (9)$$

où τ_1 et τ_2 sont des fonctions qui ne dépendent que des paramètres θ, a, l, ξ, β, ρ, σ, τ que nous venons d'introduire.

Ainsi la dérivation extérieure de l'égalité (9) peut conduire seulement ou bien à une identité ou bien à une certaine relation entre les paramètres θ, a, l, ξ, β, ρ, σ, τ. Considérons ces deux possibilités.

L'existence d'une identité permet d'affirmer que les couples orthogonaux stratifiables dont la congruence des perpendiculaires communes est isotrope existent et sont déterminés avec deux fonctions arbitraires d'un argument. En effet, la dérivation extérieure du système (1), qui détermine une congruence isotrope arbitraire, permet de compléter ce système par les équations

$$d\beta=-\xi\omega_2^3,\quad d\xi=(\xi\rho+2\beta)\,\omega_2^3-\xi\sigma\omega_1^3 \qquad (10)$$

que nous avons déjà utilisé *tacite* en développant les calculs de ce pa-

ragraphe, et alors les équations quadratiques extérieures du système de Pfaff enrichi (1) et (10) se réduisent aux deux suivantes:

$$\left.\begin{aligned}&[d\rho\omega_1^3]+[d\sigma\omega_2^3]+(\rho^2+\sigma^2+1)[\omega_1^3\omega_2^3]=0\\&[d\rho\omega_2^3]-[d\sigma\omega_1^3]+\frac{4\beta\sigma}{\xi}[\omega_1^3\omega_2^3]=0\end{aligned}\right\}\qquad(11)$$

leur déterminant $\omega_1^3\omega_1^3+\omega_2^3\omega_2^3$ n'étant pas nul, ce qui garantit l'existence de deux fonctions arbitraires d'un argument. Remarquons que si cette hypothèse avait lieu, le couple orthogonal stratifiable existerait avec une congruence isotrope arbitraire de perpendiculaires communes.

Passons à l'hypothèse qu'il existe une certaine relation entre les paramètres θ, a, l, ξ, β; ρ, σ, τ.

En dérivant cette relation et en y portant les différentielles de tous les paramètres [en vertu du lemme de M. Cartan $d\rho$ et $d\sigma$ peuvent être trouvés à partir de (11) avec deux paramètres nouveaux ρ_1 et σ_1], en vertu de l'indépendance de ω_1^3 et ω_2^3 nous aurons, peut être, deux relations nouvelles entre tous les paramètres, y compris ρ_1 et σ_1.

Il est clair comment il faut continuer, et on voit évidemment que de cette manière on arrivera ou bien à la demonstration de l'impossibilité du problème considéré ou bien à sa solution qui ne dépend que d'un certain nombre de constantes arbitraires.

Telles sont ces deux hypothèses. Nous n'avons pas encore réussi à trouver laquelle des deux a lieu en réalité, car l'étude de l'équation (9) exige des calculs difficiles.

Cependant il nous semble que le fait même de l'établissement de ces deux hypothèses présente un certain intérêt; l'existence de ces deux hypothèses doit être considérée comme la première étape dans la résolution définitive de ce problème difficile de la théorie des couples de congruences stratifiables.

Université Lomonossoff.
Moscou.

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LITTÉRATURE CITÉE

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PHYSICS

RELATIVE ABUNDANCE OF ISOTOPES

By L. B. PONIZOVSKY

(Communicated by A. N. Terenin, Member of the Academy, 28. IV. 1943)

The history of Stars and Earth could not leave unaffected the original picture of the abundance of chemical elements, characteristic of the stage at which the elements are supposed to have been formed ($T \approx 10^9$ degrees) (1). At our epoch it is, therefore, more natural to compare the relative abundance of isotopes within a single chemical element. Indeed, the percentage of isotopes of iron, potassium and uranium in meteorites and in the Earth crust is concordant; the relative abundance of the isotopes of nitrogen in organic tissues and inorganic substances is found to be the same.

The problem as to the abundance of isotopes on the Earth, formulated by Aston as far back as in 1922, still remains unsolved (2). Yet, it can be demonstrated that the abundance of stable isotopes shows a definite regularity, viz., that the abundance is a function of the stability of the nucleus (3).

This rule is subject, however, to strong deviations: isotopes of some elements are extremely abundant, whereas in others no isotopes have as yet been found. What is the cause of these deviations?

The systematics of isotopes shows (3) that the various types of formation of stable nuclei may be described by a single «series» formula:

$$N = 2^K \qquad (K = 0, 1, 2 \ldots) \tag{1}$$

From formula (1) it follows that the maximum number N of identical particles (neutrons or protons) added successively, without interruption, is equal to four.

In a number of cases the second or fourth proton is substituted by an aproton; by an aproton we understand here a hypothetical particle carrying the charge ($-e$) and otherwise identical with the proton (in weight, spin, magnetic moment).

Let us denote in the graph (Z, A) by crosses those isotopes which, according to formula (1), are likely to exist as stable ones (Fig. 1). From the figure it may be seen that the largest number of stable isotopes of one chemical element (Z) is equal to ten. Let us call the nuclei formed by addition of the first, second, third and fourth neutron, nuclei of the n; $2n$, $3n$ and $4n$-type, respectively. The nuclei formed by addition of the first and second proton will, correspondingly, be called nuclei of the p and $2p$-type. Those due to the addition of an aproton on the main

line or on the branches will be called nuclei of the a or a_1-type. The various types of branches due to the addition of two protons or two neutrons at once will be called nuclei of $2p'$, $2p''$ and $2n'$-type.

Along the main line of building of the nuclei the quantity δ of mass defect, calculated from the last particle added, shows a periodicity. There is also a parallel periodicity in the abundance of isotopes ([3]). Let us express the periodicity observed in the abundance of the various types of isotopes in the form of inequalities:

$$\left.\begin{array}{l} \text{I. } 2n > n \\ \text{II. } 4n > 3n \\ \text{III. } 4n+3n > 2n+n \\ \text{IV. } a \approx 4n \end{array}\right\} \qquad (2)$$

The nuclei which are lying on the branches of the main line of nuclei formation are less abundant than the main nuclei of the same type:

$$\left.\begin{array}{l} \text{V. } 2p_1 < 2p \\ \text{VI. } a_1 < a \end{array}\right\} \qquad (3)$$

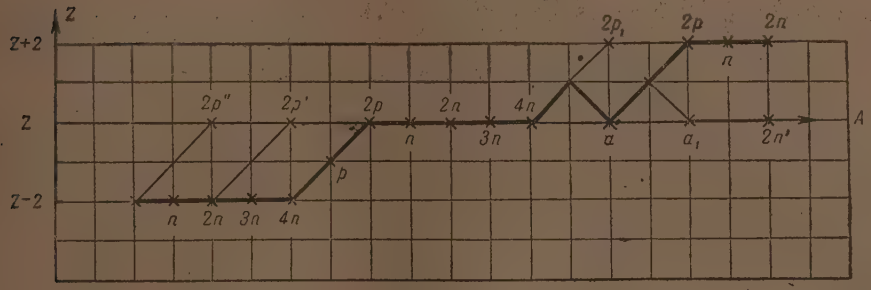

Fig. 1

And, finally, such nuclei as are due to the addition of two protons or two neutrons at once should be very rare isotopes:

$$\left.\begin{array}{l} \text{VII. } 2p'' \approx 2p' \ll 2p \\ \text{VIII. } 2n' \ll 2n, 4n \end{array}\right\} \qquad (4)$$

These qualitative rules hold true for 100 cases out of the 116 cases when a relative abundance of isotopes is known (Tables 1—11).

Nuclei of one and the same type, entering into chemical elements of an analogous isotopic structure, are likely to be equal in intensity.

In Tables 1—11 are put together chemical elements of analogous isotopic structure, in order to make comparable the intensities of isotopes of the same type entering into the composition of those elements ([4]).

It may be seen from these tables that in a number of cases isotopes of the same type actually show the same intensity. Thus, e. g., the elements Ne—Mg—Si (Table 1), Cr—Fe (Table 2), Se—Pd (Table 7), Dy—Hf (Table 8), Gd—Yb (Table 9) and Sn—Hg (Table 11) offer about the same picture. The isotopes of Ba—Dy ($2p''$, $2p'$, and $2p$), of Ru—Er (n and $2n$) and others are coincident. In a number of cases, however, analogous nuclei appreciably differ as to their intensity.

The original picture of abundance of isotopes must, of course, have changed considerably in radioactive nuclei. Thus, we have shown ([5]) that the absence on the Earth of elements with $Z=85$ and $Z=87$, as well as of a number of isotopes of heavy elements, is accounted for by the fact that these nuclei had

Table 1

Element	Type of isotope			Total %
	$2p$	n	$2n$	
Ne	90.0	0.27	9.73	100
Mg	77.4	11.5	11.1	100
Si	89.6	6.2	4.2	100

Table 2

Element	Type of isotope				Total %
	$2p'$	$2p$	n	$2n$	
Cr	4.49	83.78	9.43	2.30	100
Ft	6.0	91.6	2.1	0.28	100
Sr	0.56	9.86	7.02	82.56	100

Table 3

Element	Type of isotope					Total %
	$2p_1$	$2p$	n	$2n$	a_1	
Ge	21.2	27.3	7.9	37.1	6.5	100
Pt	0.8	30.2	35.3	26.6	7.2	100
Pb	1.5	23.6	22.6	52.3	?	100

Table 4

Element	Type of isotope							Total %
	$2p''$	$2p'$	$2p$	n	$2n$	a_1	oth.	
Ru	5	—	14	22	30	17	12	100
Er	0.25	2	35	24	29	10	—	100
Em Ra	—	—	(25)	(23)	(30)	(13)	(9)	100

Table 5

Element	Type of isotope							Total %
	$2p_1$	$2p$	n	$2n$	a_1	$2n'$	oth.	
Ca	96.96	0.64	0.15	2.07	0.003	0.185	—	100
Te	2.9	4.5	6.0	19.0	32.8	33.1	1.7	100

Table 6

Element	Type of isotope					Total %
	$2p'$	$2p$	n	$2n$	a	
Ni	67.4	26.7	1.2	3.8	0.88	100
W	0.2	22.6	17.3	30.1	29.8	100

Table 7

Element	Type of isotope						Total %
	$2p_1$	$2p$	n	$2n$	a	a_1	
Se	0.9	9.5	8.3	24.0	48.0	9.3	100
Pd	0.8	9.3	22.6	27.2	26.8	13.5	100
Th	(1)	(9)	(15)	(25)	(40)	(10)	100

Table 8

Element	Type of isotope								Total %
	$2p''$	$2p'$	$2p$	n	$2n$	$3n$	$4n$	oth.	
Ba	0.101	0.097	2.42	6.6	7.8	11.3	71.7	—	100
Dy	0.1	0.1	1.5	22	24	24	28	2	100
Hf	—	0.3	5	19	28	18	30	—	100

Table 9

Element	Type of isotope							Total %
	$2p'$	$2p$	n	$2n$	$3n$	$4n$	a_1	
Mo	14.9	9.40	16.1	16.6	9.65	24.1	9.25	100
Gd	0.2	1.5	21	22	17	22	16	100
Yb	0.06	2	9	23	17	37	12	100
U	(0.1)	(2)	(15)	(20)	(16)	(25)	(12)	100

Table 10

Element	Type of isotope									Total %
	$2p''$	$2p'$	$2p$	n	$2n$	$3n$	$4n$	a_1	$2n'$	
Xe	0.094	0.088	1.91	26.23	4.06	21.18	26.98	10.55	8.95	100
Nd	—	—	25.95	13.0	22.6	9.2	16.5	6.8	5.95	100

Table 11

Element	Type of isotope									Total %
	$2p''$	$2p'$	$2p$	n	$2n$	$3n$	$4n$	a	a_1	oth.
Sn	1.1	0.8	15.5	9.1	22.5	9.8	28.5	5.5	6.8	0.4	100
Hg	—	0.15	10.12	17.04	23.25	13.18	29.54	6.72	?	—	100

made part of an extinct radioactive family whose descendent is the now existing isotope Bi^{209} (p).

The original abundance of the radioactive isotopes of Em, Ra; Th (Fig. 2) and of U is roughly evaluated in Tables 4; 7 and 9.

The high abundance of the isotope Ca^{40} ($2p_1'$) (Table 5) is well known to be due to the β-decay of K^{40}.

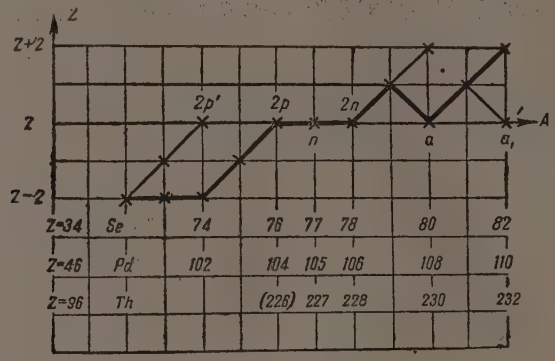

Fig. 2

The excessive abundance of the isotopes $Mo^{92,95}$ ($2p'$ and n) (Table 9) may be accounted for by the fact that these isotopes appear to be fragments of fission of uranium nuclei. The following reaction, for instance, is possible (6):

$$\left.\begin{array}{l} {}_{92}U^{235} + {}_{0}n^{1} \rightleftarrows {}_{41}Nb^{92,95} + {}_{51}Sb^{139} + 5\,(2)\,{}_{0}n^{1}, \quad {}_{41}Nb^{92,95} \longrightarrow {}_{42}Mo^{92,95} \quad \text{(stable)} \\ {}_{51}Sb^{139} \longrightarrow {}_{52}Te^{139} \longrightarrow {}_{53}I^{139} \longrightarrow {}_{54}Xe^{139} \xrightarrow{30'} {}_{55}Cs^{139} \xrightarrow{6'} {}_{56}Ba^{139} \xrightarrow{86'} {}_{57}La^{139}\ \text{(stable)} \end{array}\right\} \quad (5)$$

The increased abundance of Xe^{131} ($3n$) (Table 10) should be referred to the «radioactive chain» which probably takes place also under natural conditions:

$$ {}_{52}Te^{131} \xrightarrow{25'} {}_{53}I^{131} \xrightarrow{8d} {}_{54}Xe^{131} \quad \text{(stable)}. \quad (6)$$

The tables show that Ni^{58} ($2p'$), Zn^{64} ($2p_1$), Ti^{48} ($2n$), Te^{130} ($2n'$), Xe^{129} (n), Sm^{149} (n), Pt^{195} (n) are also endowed with extreme intensity. They probably take part in some nuclear reactions still unknown.

State Optical Institute.

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CHEMISTRY

ON COLOUR REACTION TESTS FOR ZINC, CADMIUM, MERCURY AND OTHER ELEMENTS

By V. I. KUZNETZOV

(Communicated by A. N. Frumkin, Member of the Academy, 3. VII. 1943)

The ability of certain elements to form complex anions can be used in detecting these elements by colour reactions.

In the case of zinc, cadmium and several other elements the complex anions are particularly useful. The ions of these elements are colourless and manifest no appreciable oxidation or reduction effects. Therefore, in the case of zinc and cadmium colour reactions with organic reagents cannot be based upon redox processes, or upon the formation of a complex causing a shift or intensification of light absorption which are known greatly to facilitate the search for colour reaction in the case of other elements.

The formation of complex anions has a notoriously wide use in the analysis. There have been described, for instance, the precipitations of zinc in the form of complex rhodanide by β-naphthaquinoline (1); of cadmium in the form of iodide by brucine (2); and of many other elements in the form of complex anions by the action of quinoline (3), acridine ; etc. In most of the cases these precipitation reactions are no colour reactions.

The colour reaction for zinc, cadmium and a number of other elements with stiryl dyes has been described by P. Krumholz and E. Krumholz. The yellow acidulated solutions of these dyes react with certain elements in the presence of rhodanide by taking on colours ranging from red to red-violet. V. I. Kuznetzov has reported a colour reaction for tin (ion $SnCl_6''$), based upon the sharp change of pleochroism in the crystals of the solid salt that forms when anthraquinone-<1-azo-4>-dimethyl-anilin used as reagent enters into reaction with the $SnCl_6''$ ion (4), and others.

These colour reactions are but particular cases of a general principle of colour reaction for elements forming complex anions. This principle is valid when coloured organic bases are used.

If viewed in transmitted light, the colour of a thin suspension of a solid salt of a coloured organic base is always different from the colour displayed by the solution of that salt. In the case of complex anions belonging to the same type, the difference in colour is usually the greater, the higher the atomic weight of the element.

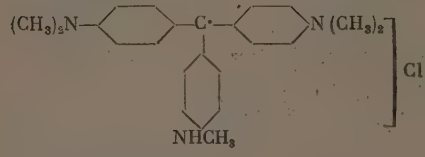
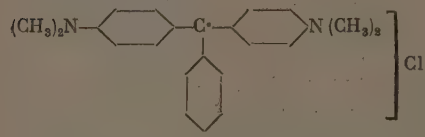
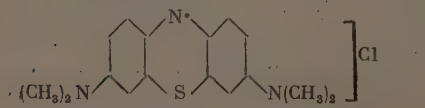
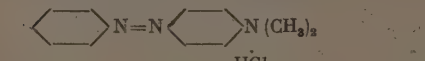
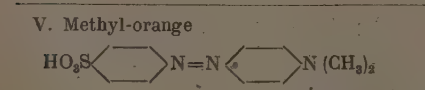
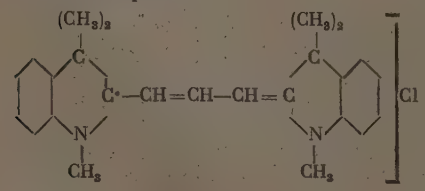
For that reason the change of colour is especially striking with heavy atoms such as Hg; Pt, Au; W etc.

However; the colour difference between the solution and suspension is not always sufficiently sharp even in the case of heavy elements. Sharp changes of

colour are observed in such coloured organic bases that serve as pH indicators and contain several basic salt-forming groups.

The ability of salt formation in the latter should not be reduced by the presence in the dyestuff molecule of substituents such as $—SO_3H$ or $—NO_2$ (c. f. dyes IV and V in the table).

Colour Reaction for Certain Elements Forming

Reagent	Complex-forming anion	Colour in	
		With reagent alone	Zn
I. Methyl-violet 	Br′	green	green
	I′	bluish-green	bluish-green
	CNS′	green	violet
II. Malachite green 	Br′	green-yellow	green-yellow
	I′	yellowish-green	yellowish-green
	CNS′	green-yellow	blue-green
III. Methylene blue 	Br′	blue	blue
	I′	grey-blue	grey-blue
	CNS′	blue	blue-violet
IV. *p*-Dimethyl-aminoazobenzene 	Br′	pink	pink
	I′	»	»
	CNS′	»	red-violet
V. Methyl-orange 	Br′	pink	pink
	I′	»	»
	CNS′	»	»
VI. Astra-phloxine 	Br′	pink	pink
	I′	bluish-pink	blue-pink
	CNS′	pink	red-violet

[1] Black-brown precipitates. [2] Violet in the case of slight acidity.

Many of the easily available basic dyestuffs are suitable for use as coloured organic bases*. Of them methyl-violet and crystal violet are very convenient, because they give sharp transitions of colour and are readily available **.

The practical procedure with these reactions is to begin by selecting suitable concentrations of the reacting substances with the aim to obtain a negative result

Complex Anions (in Hydrochloric Solution)

transmitted light

Cd	Hg^{II}	Pd^{II}	Pt^{IV}
green	blue-violet	green	green[2]
violet	blue	black-brown[1]	red-violet
green	violet	violet	blue
green-yellow	blue-green	green-yellow	green-yellow
blue-green	green	black-brown[1]	dingy-green
green-yellow	blue-violet	green	green
blue	blue-violet	violet	blue-violet
blue-violet	grey-blue	black[1]	dingy-pink
blue	violet	greyish-pink	violet
pink	pink	pink	pink
red-violet	violet	black-brown[1]	brown-red
pink	bluish-pink	brown-orange	pink
pink	pink	pink	pink
»	»	black-brown[1]	red
»	»	pink	pink
pink	blue-pink	bluish pink	pink
violet	»	black-brown[1]	black-pink
pink	bluish-pink	red-pink	blue-pink

* The salts formed by certain basic dyes with different acids have been described by E. Cheller and R. Rella.

** As a reagent use may be made of the usual violet ink which presents a water solution of these dyes.

from the blind test. This is necessary; because a certain change of colour can be produced in the blind test by using for the formation of the complex such anions as CNS′ and I′ in considerable concentration.

To put an example, the reaction may be carried out in the following way: the solution under investigation is acidulated and its other elements, if necessary, masked by adding corresponding substances. Then the reagent—the dissolved salt of a coloured organic base—is added and the resulting colour observed. The correspondence of this colour to that of the blind test may serve as a control reaction. Upon the addition of a solution of the substance (CNS′; I′; Br′ and others) that forms with the sought-for element a complex anion, the colour is found to undergo a change.

Sometimes it is convenient to add the reagent last in order.

The character of the change of colour with certain elements may be seen on the examples referred to in the table.

The colours that appear should be observed in transmitted light. In reflected light the colour is overpowered by the brilliance of the crystals in suspension. In the case of strongly diluted solutions and bright lateral illumination the scattering of light by these crystals is even more conspicuous than the change of colour.

The specificity of the colour reaction is attained both by selecting a complex-forming anion suitable for the element under determination, and by masking the other elements through their transfer to non-reacting complexes or a different valence.

By using different combinations of anion-forming and masking complex-builders, colour reactions of this kind can be made serviceable for the detection of many elements. To illustrate, some examples are presented below.

Colour Reaction for Zinc. 2 ml of the solution (neutral) under investigation are added with one drop (0.03 ml) of HCl (sp. w. 1.12), one drop of a 0.06 per cent solution of methyl-violet and two drops of 20 per cent NH_4CNS. The presence of zinc is indicated by a blue or violet colour. In the absence of zinc the solution is bluish-green. The limiting dilution for zinc is 1 : 15 000 000. The other elements are masked by adding 5 drops of saturated solution of tartaric acid. In this way zinc may be detected in the presence of cadmium at a ratio of Zn : Cd = 1 : > 10 000, and in the presence of other elements, except Au, Pt; Pd.

Colour Reaction for Cadmium. 2 ml of the investigated solution, 1 drop of HCl (sp. w. 1.12), 1 drop of 0.06 per cent of methyl-violet, 1 drop of 25 per cent Kl. The presence of cadmium is indicated by the appearance of a blue or violet colour. Limiting dilution for cadmium, 1 : 4 000 000. The detection of cadmium is possible in the presence of zinc in a proportion of Cd: Zn = 1 : >3 000, and in the presence of many other elements.

Colour Reaction for Mercury. The specificity of reaction for mercury is accomplished by using Br′ for the formation of the complex. With a small concentration of Hg^{II} a slight acidity is necessary. 2 ml of the solution (neutral) under investigation, 3 drops of 0.1 *n* HCl, 3 drops of 25 per cent KBr, 1 drop of 0.06 per cent methyl-violet. In the presence of Hg^{II} the colour is violet; in the absence of Hg^{II}, blue-violet. Limiting dilution for Hg^{II}; 1 : 2 000 000. The detection of mercury is possible in the presence of Zn, Cd, Pt and a great many other elements, except Au and Pd.

Colour Reaction for Zirconium. Precipitation of zirconium under the influence of phenyl or α-naphthyl arsonic acid in the presence of a rhodanide-containing acidulated solution of methyl-violet (bluish-green in colour) results in the appearance of a blue or violet colour. 2 ml of the investigated solution, 1 drop of HCl (sp. w. 1.12), 1 drop of 0.06 per cent methyl-violet, 2 drops of 20 per cent NH_4CNS, and 2—3 drops of a saturated solution of arsonic acid. Limiting dilution for zirconium, 1 : >1 000 000. The detection of zirconium is possible in the presence of Th in the proportions Zr : Th = 1 : >100 and with many other elements.

Colour Reactions for P, As, Ge, Si and others. If the concentration is not high; MoO_4'' gives no colour reaction; but the heteropolyacids formed by it do give a colour reaction. Owing to this it is possible to detect the elements that are able to form heteropolyacids with Mo^{VI}; viz. P, As, Ge; Si and others. The specificity of the reaction is secured by conducting it under such conditions that only the sought-for element forms a heteropolyacid.

The described principle may also be used in carrying out colour reactions for Co (in the presence of Ni), W, Pt, Au; Pd and other elements. These colour reactions are also adaptable for quantitative determinations.

Their more detailed description will be given elsewhere.

Siberian Scientific Research Institute
for Forest Economy and Exploitation.

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CHEMISTRY

SOLUBILITY (25° C) IN THE SYSTEM $NaF—AlF_3—H_2O$ (THE CHEMICAL COMPOSITION OF CRYOLITE)

By I. V. TANANAEV and J. L. LELCHUK

(Communicated by V. G. Chlopin, Member of the Academy, 11. V. 1943)

Cryolite is the usual name of a natural chemical compound corresponding to the composition $3\,NaF \cdot AlF_3$. The formula of this compound has been confirmed experimentally by Pushin and Baskov (1) and, almost simultaneously, by Fedotiev and Iljinsky (2) who investigated the binary system $AlF_3—NaF$ by the method of thermal analysis. The rational maximum on the fusibility curve; as discovered by them; corresponds to the ratio $NaF : AlF_3 = 3 : 1$. Baud (3) has investigated the precipitate formed upon mixing the water solution of NaF and AlF_3 and ascribed it the formula $3NaF \cdot AlF_3 \cdot 3.5H_2O$. On the other hand, it is known that on the industrial production of the cryolite the ratio of $NaF : AlF_3$ in the end product never attains 3, but varies within 2.7—2.8. This is also corroborated by the research made by Yatlov (4).

According to Tosterud, who has been engaged in studying the electric conductivity of mixtures between water solutions of NaF and AlF_3, the composition of the precipitate formed is $5NaF \cdot 2AlF_3$. Because of the slight solubility of the cryolite, an attempt was made by Tananaev and Talipov to use the reaction of its formation for analytical purposes (5). They found the precipitate to correspond in composition to the formula $3NaF \cdot AlF_3$; and it was only obtainable with large excess of NaF in the solution ($NaF \cdot AlF_3 = 20$ and more).

From the above it should either be inferred that the composition of the cryolite does not correspond to the formula $3\,NaF \cdot AlF_3$; or it may be supposed that the reaction between NaF and AlF_3 runs through several stages giving rise to intermediate products. It appeared therefore advisable to take up the investigation of solubility within the ternary system $NaF—AlF_3—H_2O$. The results obtained in these experiments we supplemented with data of chemical and thermographical analyses.

Investigation of Solubility in the $NaF—AlF_3—H_2O$ System. Because of the poor solubility of $AlF_3 \cdot 3H_2O$ a saturated solution of the latter, 400 to 500 cm^3 in volume, was added with increasing quantities of NaF. The mixture was stirred for 8 to 12 hours at 25°C; after wich NaF, AlF_3 and H_2O were estimated in the solution and in the precipitate. The results obtained (selected data) are tabulated below and represented graphically in Fig. 1.

The conclusions to be drawn from the examination of these data are as follows:

1. When the content of NaF in the solution ranges from 0.04 to 4 per cent (saturated solution); the sparingly soluble salt is carried down.

Weight %				Mol. NaF / Mol. AlF_3		Composition of solid phase
Solution		Solid phase		in solution	in solid phase	
NaF	AlF_3	NaF	AlF_3			
0.039	0.303	11.16	8.25	0.26	2.71	} $11NaF \cdot 4AlF_3$
0.038	0.149	8.59	6.25	0.50	2.75	
0.037	0.071	15.20	11.20	0.74	2.72	
0.118	0.059	13.70	10.21	3.97	2.73	
0.178	0.0062	14.62	10.61	57.8	2.76	
0.274	0.0021	15.55	11.63	262	2.72	
0.880	0.0009	23.73	17.44	2000	2.73	
1.28	0.0010	12.17	8.72	2319	2.79	
1.39	—	19.55	13.41	—	2.92	$11NaF \cdot 4AlF_3 + 3NaF \cdot AlF_3$
2.32	—	15.31	10.31	—	2.98	} $3NaF \cdot AlF_3$
3.52	—	25.96	17.31	—	3.00	
3.76	—	25.14	16.64	—	3.02	

2. With increasing concentration of NaF the concentration of AlF_3 diminishes from 0.53 down to 0.0011 per cent, that is nearly 500 times.

3. As the solution grows more concentrated in NaF and less so in AlF_3, the ratio of NaF : AlF changes along the isotherm from 0.23 up to 2319, showing an increase of 10 000 times.

4. In the bottom phase the ratio of NaF : AlF_3 takes two values only: 11 : 4 and 3 : 1, which corresponds to two chemical compounds: $11NaF \cdot 4AlF_3$ and $3NaF \cdot AlF_3$. The first is the main compound of the system; it is congruently soluble and exists until the concentration of NaF attains 1.4 per cent. The second compound is incongruently soluble and exists at higher concentrations of NaF than 1.4 per cent.

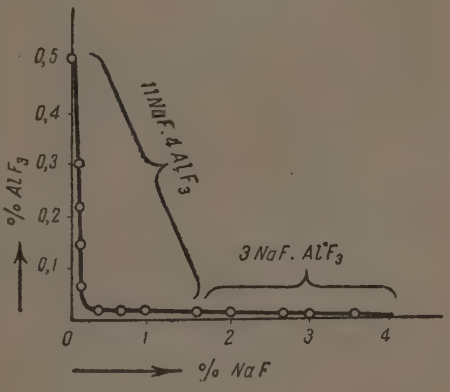

Fig. 1

These results being in conflict with the literary data on the composition of cryolite, we subjected to a careful analysis those specimens of Greenland cryolite which appeared very reliable in point of homogeneousness and mineralogical composition *. Their NaF: AlF_3 ratio was ascertained as 2.74, 2.75 and 2.72, respectively. Two artificial products obtained from the reaction of NaF with AlF_3 in one case, and with $AlCl_3$ in the other, gave 2.74 and 2.76 as their respective NaF : AlF_3 ratios. Thus; the natural samples exhibited a complete identity of composition with those produced artificially, while they corresponded to the formula of $11NaF \cdot 4AlF_3$.

Heating curves of cryolite were taken as a differential record by the method developed in this Institute. The objects under investigation were a natural (Fig. 2) and an artificial specimen (Fig. 3) of cryolite, for which the analysis data have been given above. As seen from the thermograms, the heating curve of the two samples are similar in shape and have the same characteristic points of temperature (the point of transformation of the monoclinic cryolite into the cubic one and the melting point). It may be remarked that the heating curves for the mixtures of NaF and AlF_3, corresponding to the formula 3NaF. AlF_3 had

* Two of them were received from Karpinsky Museum of Geology, and the third from the Geological Museum of the Moscow State University.

a different, less regular, form. This should be taken to mean that natural and artificial cryolite are of the same composition, 11 NaF· $4AlF_3$.

We completed our investigation with experiments on analytical, gravimetric estimation of aluminium by means of NaF in the form of 11NaF· $4AlF_3$ (2.75 NaF· AlF_3). The method evolved by us consists essentially in the precipitation

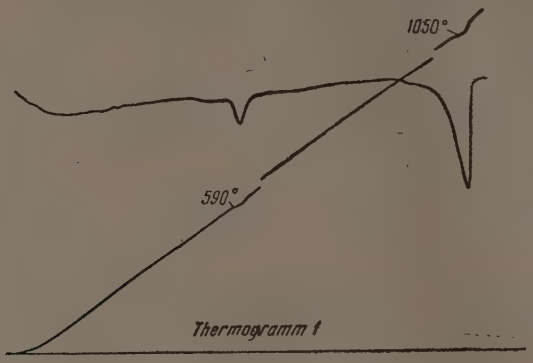

Fig. 2

of the test solution by a water solution of NaF, centrifuging of the precipitate washing it with a 50 per cent alcohol, drying at 130°C and weighing. The results obtained were quite satisfactory in point of accuracy, and it may be hoped that this method of aluminium determination will find its way into practice.

What has been found by us puts in doubt the correctness of the data on the composition of cryolite reported in literature. As may be easily seen from the solubility curve referred to here, the compound corresponding to the formula 3NaF· AlF_3

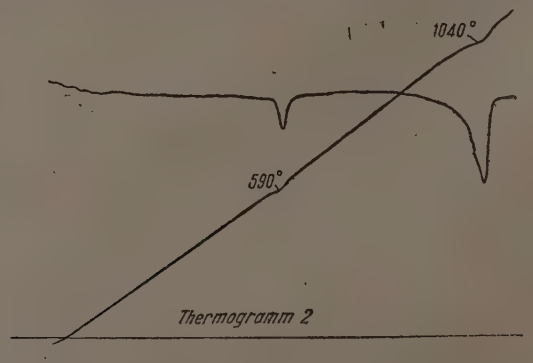

Fig. 3

is decomposed by water, and for that reason alone cannot possibly occur in nature in an open state. And as numerous samples of factory made cryolite also approximated in composition to the formula 11 NaF · AlF_3, it seems obvious tha the question of the chemical composition of cryolite is in need of revision.

Institute of General and Inorganic Chemistry.
Academy of Sciences of the USSR.

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CHEMISTRY

STRENGTH OF STRONG ACIDS

By J. V. KHODAKOV

(Communicated by V. G. Chlopin, Member of the Academy, 1. VI. 1943)

On the basis of the author's «Theory of dominating forms» ([1], [2]); the author derived the approximate formula which connected the numerical value of the strength of an acid $[X^{-q} \sim H_m]$ (molecular, cationic or anionic)—its dissociation constant with the crystallochemical radius of its anion X^{-q}:

$$\frac{1.32}{r_X} K \approx 0.84 - 0.042 \lg k.$$

The list of coefficients $K = f(q; m)$ necessary for using the formula is given in the table.

This formula is semi-empirical; since in deriving it a certain mean effective value («microdielectric constant») instead of 81, the macroscopic value of dielectric constant of water, had to be used as a measure of the screening effect of the aqueous medium upon the electrostatic forces acting at distances of the order of ionic dimensions.

m \ q	1	2	3	4	5	6	7
1	1	2	3	4	5	6	7
2	0.500	1.500	2.500	3.500	4.500	5.500	6.500
3	0.232	0.768	1.768	2.768	3.768	4.768	5.768
4	—	0.058	1.058	2.058	3.058	4.058	5.058

The first practical application of the formula was in a rough computation of the dissociation constant of ammonia as an acid, carried out in 1934 at a suggestion of A. A. Grinberg; the result coincided with the then unknown to the author experimental data of the Platinum Institute, confirmed by Schwarzenbach ([3]).

Our formula permits to give the following estimation of the order of the constants of dissociation of strong acids in an aqueous medium:

	HPF_6	$HClO_4$	HBF_4	HI	HBr	H_2SO_4	HCl	(HF)
r_X ...	3.1	2.9		2.20	1.96	2.9	1.81	1.33
k ...	10^{10}	$10^{9.5}$		10^{6}	10^{4}	$10^{2.5}$	$10^{2.5}$	$10^{-3.5}$

According to this series; the strong acids differ from each other in their strength as distinctly as the weak acids; though the levelling effect of water greatly encumbers the comparison of their strength in aqueous solutions. The series (without quantitative data) has been offered by the author as a forecast in his monograph [1] in 1934.

The problem of the comparative strength of hydrohalogenic acids which had been mooted for a long time, was already decided in agreement with the author's theoretical series, but the position of sulphuric acid in the latter was in sharp discord with the conviction still universally adopted at the time that hydrochloric acid was stronger than sulphuric acid. In support of this statement conductometric data were referred to (while the fact that H_2SO_4 dissociated in two stages was usually forgotten), or some misunderstood experiments upon the kinetics of dissolution of metals in the solutions of these acids. Not until our monograph [1] had been published, did two papers by Kolthoff and Willman [4] appear; wherein the following succession of acids in the order of their strength was established, including H_2SO_4 in glacial acetic acid as a solvent less protonophylic than water and therefore displaying no «levelling effect»:

$$\underbrace{HClO_4 > HI > HBr}_{\text{strong acid}} > \underbrace{H_2SO_4 > HCl\ (> HNO_3)}_{\text{weak acids}}$$

Sulphuric acid in this series occupies the place which is in agreement with the theory.

Hydrochloric acid is the only one among the strong acids which has been repeatedly chosen as the object for the determination of the dissociation constant. At the time when the author's theory had been published, these attempts had produced concurrent values which all characterized HCl as an acid about 10000 times stronger than it might be expected according to the theory:

Scheiner [5] . .	1924	10^8	determination of the normal potential in absolute alcohol and recomputation to aqueous solution
Ebert [6] . . .	1925	10^7	from the assumption that HCl according to molecular solubility behaves as a closing member of a series of alkyl halides
Wynne-Jones [7]	1930	10^7	from distribution coefficient

But lately Schwarzenbach [3] attempted a critical examination of these papers and recomputed the coefficient of dissociation of HCl finding it equal to $10^{3\cdot3}$ which is considerably nearer to our theoretical value $10^{2\cdot5}$. There is no doubt, however, that Schwarzenbach's calculation cannot be regarded as a final solution of the problem, since it had been connected with a number of complicated extrapolations. In my opinion, the appearance of new Raman frequencies in strong HCl solutions (from 9 *N* upwards), ascribed to HCl molecules [8], is also incompatible with the high values of the dissociation constant of HCl as given by the previous authors.

Finally, as an indirect argument against ascribing such exceptional strength to hydrochloric acid, the classification given by Brodsky may be cited [9]

strong electrolytes	diss. const.	$>10^7$ (e. g. HCl)
medium strong »	» »	in the range $10^{-2} \div 10^{-6}$
weak »	» »	$<10^{-6}$

It seems incredible that the wide range in the scale of dissociation constants from 10^{7} to 10^{-2} would be found empty, and thus the weakest of the strong acids, HCl, would be $10^{7} : 10^{-2} = 10^{9}$ (!) times stronger than the strongest of the acids of medium strength.

Thus, new experimental data accumulated since the appearance of the theory of «domitinating forms» have confirmed the correctness of the «roundabout» way to the chemical individuality of inorganic substances (the way which I discovered in discussing Kossel's theory). They have also proved that this theory, being capable to offer an unambiguous answer to any question that comes under its scope, permits not merely to anticipate the facts, but also to detect mistakes ensuing from their inaccurate observation or wrong interpretation.

Moscow Aviation Institute.

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CHEMISTRY

OXONIUM THEORY OF CATALYTIC PROCESSES OF THE TRANSFORMATIONS OF VINYL ETHERS

By M. F. SHOSTAKOVSKY

(Communicated by A. E. Favorsky, Member of the Academy, 12. VI. 1943)

In classical organic chemistry oxonium compounds have been known for a long time. Their catalytic rôle in synthesis, when oxonium compounds are intermediate products of the reactions, are well known.

The chief investigations in this field are the works of Friedel [1]; Collie and Tickle [2], Baeyer and Villiger [3], Werner [4], Kehrmann [5], Favorsky [6], Tchelintzev [7] and others. Among these classical works a particular influence upon the direction followed by the author has been produced by the investigations of A. E. Favorsky [6, 8] who discovered the capacity of diethyl ether to form oxonium compounds with bromine; iodine; sulphuric and picric acids and other substances.

However; notwithstanding the considerable amount and value of investigations in the domain of oxonium chemistry, there are no data on the catalytic rôle of oxonium compounds in the processes of the transformations of vinyl ethers.

In the investigation of the reaction of addition of water; alcohols; halogens, hydrogen halides and carboxylic acids to vinyl ethers, as well as in the study of the polymerization processes of the latter, I reached the conclusion; that the realization of all these reactions in the processes of the transformations of these ethers proceeds through the stage of the formation and dissociation and sometimes of the isomerization of intermediate oxonium compounds.

The experimental data at my disposal make it possible to express the oxonium theory of the catalytic processes of the transformations of vinyl ethers [9]. Its main points are as follows.

I. Catalytic processes of the transformation of vinyl ethers proceed under the influence of substances, capable of forming intermediate oxonium compounds with the initial ethers.

a) The classification of catalysts applicable to the reaction of transformation of vinyl ethers is based upon the unification of all the substances giving oxonium complexes, mainly with vinyl ethers and other compounds.

II. The mechanism of the catalytic action in the processes of transformations of alkyl-vinyl ethers can be reduced to the formation of oxonium compounds and to their dissociation. In the latter case reactions are realized that take no place without the use of catalysts. To this category belong reactions of the addition of water; alcohols; processes of polymerization etc. The above-mentioned catalytic reactions are expressed by the following equations:

$$CH_2=CH-O-R+HX \rightarrow \left[\begin{matrix} CH_2=CH \\ \quad\quad\quad\quad \diagdown OH \\ \quad\quad\quad\quad R \diagup \end{matrix}\right] X; \qquad (a)$$

$$\left[\begin{matrix} CH_2=CH \\ \quad\quad\quad\quad \diagdown OH \\ \quad\quad\quad\quad R \diagup \end{matrix}\right] X \rightarrow \begin{matrix} CH_2-CH-O-R+HX; \\ | \quad\quad | \end{matrix} \qquad (b)$$

$$CH_2-CH-O-R+ROH \rightarrow CH_2-CH\begin{matrix} \diagup OR \\ \diagdown OR \end{matrix} \qquad (c)$$

$$CH_2-CH-O-R+CH_2=CH-O-R \rightarrow$$
$$\rightarrow CH_2-CH-CH=CH-OR \text{ etc.}$$
$$\quad\quad\quad\quad | \quad\quad\quad\quad (d)$$
$$\quad\quad\quad\quad OR$$

b) The dissociation of oxonium compounds proceeds under the action: 1) of temperatures in the majority of cases about 100°C, 2) of water and 3) of different chemical reagents. The medium plays an extremely high rôle in these transformations. Thus; in water the dissociation of the oxonium complexes of vinyl ethers leads to hydrolysis; in alcohols the formation of alcohols takes place; in pure alkyl-vinyl ethers, at the temperature of the dissociation of oxonium compounds, polymerization processes take place.

III. Substances capable of the formation of oxonium compounds with alkyl-vinyl ethers and of addition to the double bond, at first form oxonium compounds and then undergo isomerization into addition products to the double bond. Transformations of this kind take place with alkyl-vinyl ethers in their reaction with halogens, hydrogen halides, carboxylic acids and other substances.

Depending on the case of the formation of the oxonium compound, for instance, of halogen and alkyl-vinyl ether; an active catalyst of the type of inorganic acids is either excluded or used. The majority of the substances mentioned reacts autocatalytically; according to the scheme:

$$CH_2=CH-O-R+HX \rightarrow \left[\begin{matrix} CH_2=CH \\ \quad\quad\quad\quad \diagdown OH \\ \quad\quad\quad\quad R \diagup \end{matrix}\right] X \rightleftarrows CH_3CHX-O-R$$

where X is the residue of any acid.

The scheme shows the case of a reversible and equilibrium isomerism.

The theoretical ideas advanced here are perfectly confirmed by experiment. In particular, the selection of catalysts bringing about the polymerization processes of vinyl ethers has been widened. Among the latter alkyl halides; picric acid and others should be mentioned.

Addition of Halogens and Hydrogen Halides to Alkyl-Vinyl Ethers. Data found in literature on the addition of halogens to vinyl ethers by Wislicenus ([11]), Meyer and Lenhardt ([12]), as well as on the properties of α-halide-ethers by Cocker; Lapworth and Walton ([13]) and Swallen and Boord ([14]), are supplemented by our experimental data; and the mechanism of these transformations is explained in the light of the oxonium theory.

α-β-dibromo-ethyl-isopropyl Ether. The high liability of vinyl-isopropyl ether to form oxonium complexes makes difficult its bromination under usual conditions and gives low yields of the reaction product. The bromination of this ether under condition of heating on a boiling water bath in a solution of CCl_4 leads to the formation of the dibromide, the yield being 90 per cent of the theoretical.

The dibromide had the following constants: b. p. 78—80°/16 mm, d_4^{20}=1.6625; n_D^{20}=1.4990.

The molecular weight determined by the cryoscopic method in benzene was 244, calculated for $C_5H_{10}OBr_2$; 248. Molecular refraction: MR' found 43.48; MR calculated 42.46; exaltation MR'—MR=1.02.

Analysis: Found %: C—40.39; 40.31. H—6.29; 6.35. Br—64.89; 65.01. Calculated for $C_5H_{10}OBr_2$ %: C—40.22. H—6.19. Br—64.97.

Properties of the dibromide: a) When refluxed with water the substance yields bromoacetic aldehyde (b. p. 105°C) and isopropyl alcohol (b. p. 81°C). b) Under the action of a 10 per cent aqueous solution of Na_2CO_3 the dibromide is cleaved with the formation of bromoacetic aldehyde, isopropyl bromide (b. p. 59—60°C; n_D^{20}=1.4250) and isopropyl alcohol. c) Under the influence of a 5 per cent solution of KOH in isopropyl alcohol the dibromide is converted into bromo-ethyl-diisopropyl ether. d) Bromination of the dibromide.

123 g of the dibromide were heated on a boiling water bath and to it bromine was added gradually. Bromine is rapidly discoloured. Towards the end of the reaction there was a considerable evolution of HBr. 80 per cent of bromine from the theoretical amount were added. Distillation made it possible to isolate from the reaction products a substance, b. p. 120—125°C/20 mm, d_4^{20}=1.9388; n_D^{20}=1.5330.

Molecular weight determined cryoscopically in benzene was 325.4; calculated for $C_5H_9OBr_3$; 328. Molecular refraction: MR' found 52.10; MR calculated 50.21; exaltation MR'—MR=1.89.

Analysis. Found %: C—18.79; 18.90. H—2.99; 3.07. Br—74.05; 73.78. Calculated for $C_5H_9OBr_3$ %: C—18.49. H—2.82. Br—73.30.

When refluxed with water, or under the action of a 10 per cent aqueous solution of Na_2CO_3 in the cold, the tribromide undergoes cleavage with the formation of dibromoacetic aldehyde (b. p. 141—142°C), isopropyl bromide and isopropyl alcohol. Therefore, the substance obtained has an oxonium structure: α-β-dibromoethyl-isobutyl ether

$$\left[\begin{array}{l} \qquad\qquad\quad CHBr=CH \\ (CH_3)_2CH-CH_2 \quad -CH_2 \end{array}\!\!>\!\!OH\right] Br$$

This dibromide was obtained similarly with α-β-dibromo-ethyl-isopropyl ether. B. p. 91—92°C/4 mm; d_4^{20}=1.4860; n_D^{20}=1.4922.

Molecular refraction: MR' found 53.52; MR calculated 51.70; exaltation MR'—MR=1.82. Molecular weight determined by the cryoscopic method in benzene was 272; calculated for $C_7H_{14}OBr_2$; 274.

The dibromide is hydrolyzed by water, by a 10 per cent aqueous solution of Na_2CO_3 and is also capable of a further bromination under heating.

On the basis of the composition and the properties of dibromo-ethyl-alkyl ethers, for them the oxonium structure should be accepted:

$$\left[\begin{array}{l} CHBr=CH \\ \qquad\quad R \end{array}\!\!>\!\!OH\right] Br; \quad R=Alk.$$

Institute of Organic Chemistry,
Academy of Sciences of the USSR.

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GEOLOGY

ON THE ORIGIN OF SETTLING LOESS-LIKE LOAMS

By N. J. DENISSOV

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One of the characteristic features of settling loesses and loess-like loams, which is, however, utterly neglected when discussing their origin, is their extremely low natural moisture content. To give an example, within the Eastern Cis-Caucasus beginning from a depth of 1.5—2.0 m from the surface, the moisture content of the grounds remains constant throughout the year; its magnitude in the superficial horizons does not exceed 8—9 per cent. The increase of humidity content with depth proceeds very slowly, so that at a depth of 18—20 m it does not exceed 9—11 per cent, which value is lower than the mean values of maximum molecular moisture capacity (16—18 per cent). An idea as to the moisture content of loess-like loams at the region of the village Soldatskaya, Stavropol district, may be gained from the following data referring to the rainy autumn period.

Depth, m	0.5	1.0	2.0	4.0	6.0	8.0	10.0	12.0	16.0	18.0
Moisture content,%	21.9	10.0	9.9	9.5	10.1	10.6	9.7	10.1	11.0	10.8

An insignificant natural moisture content is also characteristic of the loesses and loess-like loams of elevated terraces and watershed areas of the Ukraine ([3], [9], [10]) and Central Asia ([1]).

If we consider typical settling loesses and loess-like loams to be aeolian formations, their small natural moisture content can well be explained by the conditions of their genesis.

Deluvial and proluvial formations, deposited under arid conditions, may also be low in moisture. If formed in this way, the rock could have dried and accumulated moisture, but not throughout its thickness, hence the low moisture content.

If we were to adopt alluvial origin of loesses, of Ukrainian loesses in particular, which is considered possible by some students ([2]), and doubtless by others ([13]), then it should be recognized that by the recent period a considerable decrease in the moisture content of these soils has taken place. Such an assumption is clearly in disagreement with the tendency of these soils to settling. Besides, the very possibility of such a profound and considerable drying, as typical of loesses, is doubtful.

In the first place it should be noted that the decrease in the moisture content of loess-like loams to a value appreciably lower than the one characterizing their water-retaining capacity, cannot be caused by the sinking of the level of under-

ground water, due, say, to a subsidence of the base level of erosion of the country.

No biological or chemical drying seems to be probable, either. It remains to consider the possible part of evaporation of the moisture which had formerly saturated the soil.

It is known that evaporation of the ground water cannot take place unless their level is in immediate proximity to the surface. After this level has sunk by a value exceeding the height of the capillary rise, further evaporation ceases, as shown by experimental data ([5]).

A condition necessary for the drying of soils to a considerable depth (20 m and more) is the possibility of an upward migration of moisture. The migration of water in the form of vapour will bring about no effect of drying ([6], [7]). The above data on moisture content in soils, as varying with depth, show that for lack of the necessary difference in the thicknesses of water films surrounding the particles, the upward migration of water in the form of a film cannot be recognized as the possible cause of the drying of ground. Numerous experimental data ([8], [11]) go to support this conclusion.

In his analysis of the data as to the low natural moisture content of the loess-like loams of the Alkhanchurt valley, A. F. Lebedev ([7]) assumed their dryness to be an inherent one. Fully sharing this view, we arrive at the conclusion that the present dry condition of thick beds of loesses and loess-like loams is not a sequence of a reduced moisture content of ground formerly saturated with water. On the contrary, the general data as to a drier climate during the epoch of loess formation, as compared to that of the present time, give us ground to assume that the present condition of moisture content of these soils has been attained as a result of a slow secular process of moisture accumulation. This is evidenced, e. g., by the formation of natural settling, under which the moisture content of the soils is higher than outside them. In the Tereck-Kuma steppes the formation of saucer-like depressions takes place after abundant rains up to the present time.

The extensive development of settling soils has been observed safely enough within the Eastern Cis-Caucasus and Central Asia. It is not, however, encountered throughout these regions. Their absence in terraces composed of alluvial deposits is quite comprehensible. But within the boundaries of water-divide plateaux, too, settling grounds are not observed all along the channels or throughout the area irrigated.

Against the general background of settling soils there occur «spots» of non-settling ones; the process of self-condensation of these has been completed as a result of a higher moisture content and of the effect of water films ([4]), which is a wedging and friction reducing one. In this way there occurs a loss of such characteristic peculiarities of typical loesses as high porosity, low moisture content, and settling tendency, and the conversion of them into degraded loesses distinguished by W. A. Obruchev ([12]).

There are data showing that settling of soils takes place in the Rostov region and in the south of the Ukraine ([9]). However, there they are not so extensively developed and not so significant as in the Eastern Cis-Caucasus and Central Asia.

The settling soils in the south of the European part of the USSR are developed as detached «spots» against a general background of soils which already underwent self-condensation. This shows that at the epoch preceding the recent, moister one, settling loesses and loess-like loams were more extensively developed in the USSR than at present, covering the south of its European part, the piedmont part of North Caucasus, and Central Asia. The progressive degradation of settling soils connected with an increase in the moisture content of the soils results in the fact that the northern boundary of development of settling loess-like loams is gradually shifted south and south-eastward. Traces of the shifting of this boundary are evidenced by «spots» of settling soils which, owing to their persistent low moisture content, still remain outside the modern boundaries of an extensive development of settling soils.

The above data on the moisture content of loesses and loess-like loams and its changes with time prevent us from considering these soils as alluvial formations.

The causes of the origination of these characteristic features of typical loess-like rocks, such as high porosity, low moisture content and settling tendency, can well be interpreted upon the assumption of their aeolian origin, and to a lesser degree, of a deluvial and proluval formation under arid conditions.

S. Ordjonikidze Industrial Institute.
Novocherkassk.

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GEOLOGY

THE BITUMINOUS HORIZONS OF THE EASTERN SLOPE OF THE URALS AND OF THE WEST-SIBERIAN PLAIN

By G. E. RIABUKHIN

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Within the recent years, 1942 in particular, as a result of field work and drilling carried out on the eastern slope of the Urals, within the West-Siberian lowland and the western marginal parts of the Central Siberian platform, a number of bituminous horizons have been established. Part of them proved to contain actual oil occurrences, which fact seems to be promising with respect to the discovery within the West-Siberian plain of economic oil deposits, provided adequate favourable structures are found.

Below we give a brief summary in a stratigraphic sequence, in ascending order: Upper Silurian—Lower Ludlow—Kolonga series (4).

Black limestones with an abundance of *Amphipora* and *Stromatopora*. The bituminous nature is pronounced, in addition to the colour and characteristic smell when struck, in the presence of calcite stained with petroleum and of crusts of brittle bitumens. The total thickness of the Kolonga series for the eastern slope of the North Urals is about 80 m.

In the Upper Silurian of the western marginal parts of the Siberian platform in the Turukhansk region, on the Sukhaya Tunguska river, there are also bituminous horizons with direct oil shows (2, 3). A fauna of *Stromatopora* and corals indicates that these beds refer to the Llandovery and Wenlock. The so-called Devil's series (3) of the Upper Silurian is represented by grey cavernous and porous dolomites, profusely impregnated with liquid and semi-liquid bitumens. Within the area of the mouth of the Devil's river the bitumens form a plastic mass; melting easily when heated by the rays of the polar August sun, gradual transitions being observed from dry coarse bitumens to semi-liquid ones. The bitumens are strictly confined to algal intercalations of limestones (series Devil's, Pokossovsky and Kostinsky) and have not suffered any important migration.

The most conspicuous oil shows have been recorded in the Devonian deposits of the eastern slope of the Urals. Here, aside from a number of bituminous horizons, we have investigated two horizons with direct oil shows, belonging to the Eifelian and Givetian stages of the Middle Devonian. The first horizon of the Devonian consists of *Amphipora* limestones of the Eifelian stage, which in the region of the «Krasnaya Shapochka» bauxite deposit form the roof of the bauxite bed. In the upper part of the *Amphipora* limestones fauna is absent, and the limestones show traces of hydrogen sulphide contamination. The thickness of the *Amphipora* limestones is 30—50 m. They have been traced along the strike over a distance

up to 30 km (according to the data of shallow drilling of «Aluminrazvedka»). In the *Amphipora* limestones there occur drops and films of oil, as well as stringers following thin fissures, and a filling of caverns with brittle bitumens, the petroleum nature of which has been proved by numerous investigations (O. A. Ratchenko, R. A. Vener, M. E. Levenson). An examination of cores from drill-holes of «Aluminrazvedka» has revealed that every tenth shallow hole reaches shows of liquid oil; and every third hole, solid bitumens.

The second bituminous horizon of the Middle Devonian belonging to the Givetian stage is extensively developed on the eastern slope of the North Urals and is represented by an alteration of platy bituminous limestones containing in profusion a small suppressed fauna of brachiopods, gonatites and pteropoda black shales and polymict sandstones (effective porosity from 6—8 to 20 per cent). Total thickness from some dozens of meters to 200 m. Among the shales on the Kalya river there have been found intercalations of sapropelite shales, passing into sapropelite coals, containing up to 24 per cent primary tar, from 10 to 20 per cent ash, and 60 per cent volatiles to dry shale, with a high hydrogen content (up to 10 per cent). In the limestones there are films of oil and crusts of dry bitumen. From its lithology, fauna and microscopic structure the rocks described are similar to the Domanik facies of the eastern slope of the Urals ([6]), but with guide forms older as compared to the western slope.

On the eastern slope of the Middle Urals, in the Lower Carboniferous deposits with a total thickness of the limestones up to 1200 m, up to two horizons with a high bitumen content have been recorded: first, a 60-m thick series of limestones of the lower part of the C2A horizon, and the overlying light-grey limestones of $C_1$2B. Along the Rezh and Iset rivers K. S. Maslov has observed direct oil shows in the Carboniferous in the shape of asphaltite films along calcite fissures. It is known that in the Devonian and Lower Carboniferous direct oil shows have been recorded also in the Kuznetsk basin and Minusinsk depression, as well as in the Taimyr folded zone (on the Tareya river). The deposits of the said provinces pitch under the Meso-Cenozoic of the West-Siberian plain.

As to the Permian deposits of the eastern slope of the Urals, in which the possible presence of oil has been strongly hoped for by some investigators, the results of the works of the Institute for Geological Survey in 1942 and of microfaunistic determinations suggest for them an age not younger than the Carboniferous. Thus, the presence of higher divisions of the Palaeozoic (Upper Carboniferous and Permian) may be assumed only within a considerable distance east of the Urals under Meso-Cenozoic deposits of the lowland.

If for the western slope of the Urals (with a pitch of bituminous rocks of the same type as east-uralian ones according to facies and age) we have oil deposits in the piedmont depression and platform, the same possibility should be expected with a pitch of the Palaeozoic rocks of the eastern slope of the Urals. The main difficulty of the problem lies in the presence of Palaeozoic facies favourable for oil formation under the mantle of Meso-Cenozoic rocks, under conditions of quiescent folding, distinguished from the complex tectonics of the eastern slope of the Urals. Here we are assisted by the use of geophysical methods of investigation. Thus, according to data of magnetic and gravitational investigations; east of the Urals, at a distance of 100—150 km, the narrow foothill depression expressed in a system of sharp anomalies is followed by a quiescent zone of development, probably of the Upper Palaeozoic, to which areally a group of springs is confined, containing potassium salts; iodine and bromine (Sosva springs).

The eastern slope of the Urals furnishes for the West-Siberian plain a clue to the knowledge of the possible presence of oil in the Triassic coal-bearing deposits: the idea of their eastward passage within the plain to an oil facies was expressed as early as 1932 by Gubkin ([1]). Among the coals there are sapropelites. When drilling within the lowlands, no Triassic deposits have been as yet encountered, and only on extreme north-east (Ust-Port district) to this age refer sandstones with liquid oil shows struck by deep drilling.

The greatest interest is presented by the Upper Jurassic deposits exposed in 1941 by deep drilling of a hole in the region of the Gankino station, 60 km east of Petropavlovsk. These deposits are characterized by an Upper Jurassic fauna determined by G. E. Krymholz: *Cylindrothentes* ex gr. *magnificus* d'Orb. and *Belemnites* ex gr. *porrectus* Phill.; as well as by microfauna, and represented by sediments of the marine coastal facies as an alternation of sands, with an effective porosity up to 30 per cent, and clays. The total thickness of these deposits is up to 25 m; it increases north of the Gankino station, within a distance of 20—30 km, to some hundreds of meters (6). Confined to this horizon at Gankino is a liberation of combustible gases and salt waters similar to the waters of the Sosva salt spring on the eastern slope of the Urals. The presence of liquid oil horizons is known from the data of prospecting carried out at Nordwick, and shows at Ust-Port.

The superjacent Lower Cretaceous deposits have been exposed in the West-Siberian plain by some isolated holes and consist of an alternation of clays and sands with rare sandstone intercalations; in the Gankino hole for the Neocomian per 331 m of thickness we have 10 per cent of sands with an effective porosity up to 30 per cent and numerous gas shows. In the region of Ust-Port the Lower Cretaceous deposits, according to drilling data, are impregnated with liquid oil. As to the overlying thick red continental deposits of the Apt-Albian, these beds should be only considered from the standpoint of the part they play in sealing and preserving the oil deposit (6).

The Upper Cretaceous deposits extensively developed in the West-Siberian plain are represented by homogeneous argillaceous beds almost entirely deprived of sands and without any marked organic carbon content. The conditions of an open sea basin in the Upper Cretaceous are unfavourable for oil formation. Of similar nature are the sediments of the Palaeocene, Eocene and Oligocene seas. The Neogene deposits are represented by a continental formation, and from their type, as well as from their horizontal mode of occurrence in thin beds, cannot be of interest.

The eastern and particularly south-eastern part of the West-Siberian plain is of little promise as compared to the other parts of the plain, because of the extensive development of continental Cenozoic and Mesozoic deposits.

In conclusion it should be noted that the supposed epochs of oil formation during the Meso-Cenozoic for the West-Siberian lowland coincide with the epochs of oil formation in the adjacent geological provinces—the Emba oil-bearing region and the Djungar province of New China; where the productive beds are of Jurassic age (China), as well as Jurassic and in part Cretaceous (Emba).

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PLANT PHYSIOLOGY

PHOTOSYNTHESIS AS AFFECTED BY THE DURATION OF WATER WITHDRAWAL FROM ASSIMILATING TISSUE*

By V. A. BRILLIANT

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When the photosynthetic activity of plants is studied in relation to the provision of their assimilating tissue with water, the problem is not exhausted by considering only the extent to which the plants experimented upon have been deprived of their water. There arises the further question of the rate and duration of the dehydration process which may, possibly, also have a certain influence on the photosynthesis. Kaltwasser (1) transferred aquatic plants directly from water of the air or subjected them to the action of a medium gradually decreasing in humidity. When the plants were taken back to the water, they showed the same rate of photosynthesis in both cases. Yet, that author made his determinations of the rate of photosynthesis after a considerable interval had elapsed since the plants were placed again in the water, so that they had had time enough to recover from withering, and this may possibly account for the results obtained by him.

In my experiments the plants were allowed to loose the same amount of water more slowly—over a solution of sulphuric acid, or more rapidly—in the air, and after being taken back to the water were at once tested for the rate of photosynthesis. The data in Table 1 are the results of two experiments with the leaves of *Potamogeton praelongus*.

Table 1

Conditions of drying	Duration of drying in min.	Loss of water in % to raw weight	Photosynthesis	
			in mgs of O_2 per hour per 1 g of dry matter	% to control
Control	—	—	5.87	100
In the air	11	7.8	8.19	139
Over 17% H_2SO_4	8	7.8	5.24	89
Control	—	—	7.03	100
In the air	3	17.1	5.13	73
Over 17% H_2SO_4	13	17.1	0	0

* This research has been carried in collaboration with G. E. Schulz.

The figures referred to in Table 1 show that a gradual drying of the tissue calls forth a marked reduction in the rate of photosynthesis which is more or less strong according to the extent of dehydration; but is always much stronger than that caused by rapid drying with the same amount of water lost. In fact, even an increase of the rate of photosynthesis is sometimes observed after rapid drying.

In greater detail the question was explored on the leaves of *Hibiscus rosa sinensis*. This time the immediate effect of the withdrawal of water was studied and not the after-effect, which was necessarily the case in the experiments with aquatic plants. The experiment was run with severed leaves which were dried over sulphuric acid (1st set of tests) or put with their petioles in salt solutions (2nd set). In the long runs, moreover, the glasses with the leaves were placed in a moist air with the aim to reduce the loss of water by transpiration to a minimum, so that all dehydration that would occur might be ascribed to the action of the salt solution. The petioles of the control leaves were immersed in water. The rate of photosynthesis was determined by means of a Boissen-Jensen apparatus, slightly modified. Stomatal aperture was controlled according to Molish. The results of these tests are given in Tables 2 and 3.

Table 2

Test	Vapour pressure in %	Duration of drying in hours	Loss of water in % to raw weight	Photosynthesis, mgs CO_2 per 100 cm² per hour		Stomatal aperture*
				test	control	
1	0**	½	1.0	4.9	4.9	+
2	80	1½	1.7	8.5	7.1	++
3	0	1½	4.5	11.9	9.8	++
4	0	1½	4.6	7.5	7.1	++
5	0	2½	4.8	7.1	5.4	++
6	in the air	1½	4.8	5.8	3.1	++
7	0	1	8.3	8.5	3.6	++
8	90	19	6.7	10.8	12.5	++
9	85	18	7.0	4.7	7.3	++
10	90	18	9.3	5.2	10.8	++
11	85	18	9.6	4.7	7.2	++
12	80	20	22.7	0.4	5.7	+—

* ++ well opened. + slightly opened. +— nearly close. — close.
** Over strong H_2SO_4.

Table 3

Test	Conditions of dehydration		Loss of water in % to raw weight		Photosynthesis, mgs CO_2 per 100 cm² per hour		Stomatal aperture
	conc. NaCl in g mol	duration	before exposure	after exposure	test	control	
13	0.7	20 min.	0.8	9.0	13.2	16.5	++
14	0.7	35 »	1.3	11.2	15.2	14.2	++
15	0.5	60 »	7.2	17.9	10.0	7.6	++
16	0.7	35 »	7.7	12.0	5.9	11.7	++*
17	0.5	18 hrs	7.7	14.2	0.6	8.9	—
		Leaves in moist air					
18	0.5	18 hrs	0	1.2	9.8	10.0	++
19	0.8	20 »	0	1.5	0.5	3.2	+
20	1.0	21 »	0	3.0	3.6	8.9	++
21	1.0	18 »	0	3.6	4.3	6.6	++
22	0.4	19 »	0	16.9	—0.4	9.0	++
23	0.5	1½ »	0	4.2	6.5	2.9	++
24	0.5	2 »	0	7.4	8.7	6.0	++

* Young leaves.

It may be seen from Table 2 that in all short runs, with the exception of test 1 in which the rate of photosynthesis appears to have been reduced by the slight stomatal aperture, and test 4 which was run with a young leaf, especially sensitive to dehydration, the rate of photosynthesis was more or less higher in the dried leaf than in the control (tests 2, 3, 5—7). On the other hand, in the case of slow dehydration (runs 8—12) the rate of photosynthesis was always lower in test leaves than in control, though the loss of water was the same or even less (runs 8 and 9 compared to 7).

The figures of Table 3 bring plainly out the rôle of the time factor in the relation between photosynthesis and dehydration. If comparing the runs 15 and 17 it may yet be supposed that the results of the latter are more due to the closing of the stomata than to the action of dehydration, no such a conclusion can possibly be derived from the runs in moist air which prove definitely that under a long action of the salt solution the dehydration causes a stronger depression of the photosynthetic activity than under short. Very representative in this respect is the comparison of runs 23 and 24 with runs 20 and 21.

An interesting case is the behaviour of the young leaf in the test 16. A loss of water of about 8 per cent caused in the case of this leaf a nearly twofold reduction of the rate of photosynthesis, whereas an equal loss of water in test 15 resulted in an increase by 32 per cent as compared to the control. Also a comparison of tests 16 and 14 shows that in the former case (a young leaf) the loss of water was 7.7 per cent and the decrease of the rate of photosynthesis 48 per cent, whilst in the latter case a leaf grown under equal conditions of dehydration had lost only 1.3 per cent of its water and showed a slightly enhanced photosynthetic activity compared to the control.

Like its immediate effect, the after-effect of the dehydration upon the photosynthesis is much more pronounced if the assimilating tissue was long held in the dehydrated condition. This is proved by the experiments of Walter [3], Stalfelt [2], Kaltwasser [1] and by some of my own data.

It will be obvious that the slower the withdrawal of water and the longer the dehydrated state of the assimilating tissue, the stronger in most cases will be the resulting depression of the photosynthesis, even if the same amount of water is eventually lost. This depression of the photosynthetic activity will not vanish immediately after the normal store of water is restored in the tissues.

It is likely that under conditions of a slow dehydration the living colloids undergo irreversible alterations which in the case of a rapid and short dehydration do not set in unless a much greater loss of water has been sustained.

W. L. Komarov Botanical Institute.
Academy of Sciences of the USSR.

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HISTOLOGY

ON THE CULTIVATION OF NEUROGENIC TUMOURS OF MAN OUTSIDE THE ORGANISM

By N. G. CHLOPIN

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The experimental histological analysis of the various subsidiary components of the nervous system made by the present author allowed him to investigate a number of specific histological features of the tissues that are classed into a unified glial-ependymal or ependymal-glial tissue type, and to establish different modifications of a peculiar neuroglial mode of growth outside the organism ([1-4, 6, 7, 14-18]). Further development of this series of works gave among others rise to experimental histological investigation of the tissues of neurogenic tumours, in the first line in man. In the analysis of the features of human tumoural material quite an outstanding part belongs now to the method of explantation. This is especially true since the time when Gey and Gey ([5]) have worked out their method permitting to obviate a number of technical difficulties. Applied by Timofeyevsky and his co-workers ([12, 13]), this method gave most diverse and valuable results. The studies devoted to neurogenic tumours in man are rather few in number. Among them investigations by Pinkus ([10]), Russel and Bland ([11]) are noteworthy, as well as experiments by Smirnov, referred to in a review by Timofeyevsky ([13]), and the data of this latter writer ([12, 13]).

In the first half of 1941 I started experiments on a number of various neurogenic tumours in man; the material was mostly explanted in vials after the method of Gey and Gey modified by Timofeyevsky, or according to the method of a suspended drop. The bottled cultures gave in all cases good results and were studied stage by stage, up to one and a half or almost three months long development outside the organism. Cultures in a suspended drop were not always successful; being characterized by a much weaker growth and proliferation. I shall briefly analyse here the results of the investigation of the following four tumours: 1) a glioblastoma at no high level of differentiation, localized in the left frontal lobe of the large hemispheres; 2) a fibrous astrocytome of the cerebellum; 3) an oligodendrogliome of the brain, showing foci of calcification; 4) a tumour of the *angulus ponto-cerebellaris*, or a neurinoma of the auditory nerve*. All tumours had an appreciably or strongly liquefying effect upon fibrin clots.

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In spite of certain distinctive features. the two former tumours displayed several features in common and the growths produced by them belonged to two main types, involving migration of macrophage-like glial elements. Part of the tumour cells were supplied with thin branching processi; when growing, they assumed a complex astrocytic and neuronoid shape, and could form peculiar interlacements in the zone of growth. Early stages of growth of the second tumour often showed a misleading likeness with the pictures of growth of nerve fibres, so typical of tissue cultures; in the given case they were undoubtedly nothing else than thread-like cytoplasmic processi of the tumour's neuroglial elements which had not yet migrated from the central fragment. The «neuronoid» cells bore a different number of outgrowths; occasionally showing an intricate branching, whose path could often be retraced all along its length. In some cases they were 1 mm and more in length. In the cultures from the first tumour the cells assumed a rather grotesque shape.Owing to amitotic constrictions, many of these elements grew bi- or polynuclear. Part of the polynuclear cells were alredy present in the original material, others could easily be seen to form in the explants. Cultures with a prevalent growth of neuronoid tumoural cells showed a poor mitotic activity, if any at all. I am inclined to interpret the pictures of this type of growth as a result of a specific histotypical differentiation of tumoural cells, accompanied by reduced mitotic activity. The second type of growth of cultures from those two tumours represented poorly differentiated growths typical of neurogliae; they took on the shape of cellular membranes, strata or currents. The tumoural cells were thereby transformed into polygonal, spindle-like or dendritic cells of various outlines. Such cultures showed a much higher mitotic activity. Some of the explants contained very numerous mitoses. The cells of tumoural membranes proved in part of the cases able to reassume their complex ramified shape and to form thin thread-like processi. Tumoural growths of these two types show an obvious resemblance with the transformations outside the organism of a normal glia from the wall of lateral ventricles and the spinal cord, which also gives complexly ramifying astrocyte-like and neuronoid forms of cells, and characteristic poorly differentiated growths.

One of the distinctive features of the elements of these two tumours was a still more involved shape of cells which assumed an entirely neuronoid aspect.

The neuronoid shape of the glial cells observed in such an exaggerate form in the tumoural material seems to be of great importance in principle. The morphological likeness between the neuronoid glial cells and the genuine neurons may be interpreted as a manifestation of close relationship in those elements of the nervous system whose significance is entirely different, but which have developed in the phylo- and ontogeny from the very same source; being therefore closely linked together. In the first of the tumours analysed the ramified outlines of the cellular bodies that are untraceable in the original material, gradually became quite distinct in the central bits of the explants, as in the case of normal glia.

The elements of the second tumour displayed in the original material the same involved interlacement of processi when treated in the usual manner. Unlike cultures from the central nervous system, the central fragments of tumoural explants failed to transform into continuous glial massifs, but preserved their more or less loose consistency.

The third tumour of the central nervous system represented under the microscope a mass rich in cells of now elongated and then polyhedral shape; the central parts of this mass were overfilled with tightly packed spherical calcareous concretions of various size. The cells situated around the calcareous spheroids usually assumed an epithelioid appearance. This tumour was remarkable for its intense growth; not only in bottles; but in a suspended drop as well; its mitotic activity was high. The cells of the tumour underwent alterations in three principal directions: they transformed into macrophage-like or very fine lymphocite-like elements; or else they grew as cellular currents; strands and flat membranes. The central region of the zone of growth assumed occasionally the character of a massif. The cells showed elongated, less frequently polygonal outlines; they formed rather long, almost thread-like processi with varicose thickenings. The cellular

nuclei were; as a rule; of round or slightly oval shape; and contained one or two large nucleoli each. The zone of growth offered a general aspect of poorly differentiated glial growths; part of these assumed occasionally the shape of astrocytes, which was, however, much less conspicuous than in the previous cases. Not infrequently there were met binuclear, less often, three- or polynuclear cells of relatively small dimensions. The tissue of this tumour was evidently endowed with a high degree of cataplasia; its histoblastic potencies could not be duly evaluated within the period of cultivation which lasted 1 month and a half.

The cultures of the tumour of the *angulus ponto-cerebellaris* showed an exceedingly high fibrinolysis which often set in prior to the appearance of the first signs of extensive growth. In such cases the central fragment was soon found to float in a drop of liquid and might perish without having formed a zone of growth unless passaged at due time. However, by means of frequent passages we succeeded in obtaining extensive growths from this tumour at early stages of cultivation beginning from the first days and almost up to a three month period; mitotic division of growing tumoural elements could also be observed. The zone of growth formed by the cells of this tumour at all stages of cultivation was of the nature of normal Schwann cells. The growth of the latter was analysed by me in one of my previous studies concerned with *nervus vagus* of the rabbit ([16]). Part of the tumoural cells mostly sent forth typical narrow-cellular strands; as well as isolated cells of a strongly elongated or thread-like shape. The rest acquired a macrophage-like character. For sake of comparison we explanted also particles from a normal auditory nerve of a newborn rabbit. These cultures gave a growth of type similar to that of the tumour described above, and to the *n. vagus* investigated in my earlier work.

To my opinion, these observations make quite unrefutable the neurogenic nature of neurinomas which have been supposed by some authors ([7],[9]) to originate from connective tissues and wrongly termed «perineural fibroblasts». I have already had occasion to argue against this conception on the ground of a study of the histoblastic potencies of normal Schwann cells. The experimental histological analysis of the corresponding tumoural material solves this problem without leaving room for any objections.

I give here but a most general analysis of the data obtained. When compared to our material for normal ependymal-glial tissues, they go well to substantiate the conception according to which tumoural cells manifest with a varying completeness the cycle of transformations which is peculiar to the respective normal cells in the case of non-tumoural proliferous processes. The manifestation by tumoural cells of histological peculiarities common to a given type of tissue may, at the same time, be distinguished by a more or less conspicuous specific «tumoural» singularity.

S. M. Kirov Military Medical Academy.

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HISTOLOGY

GROWTH AND TRANSFORMATIONS OF EPITHELIUM OF A PREGNANT RABBIT WOMB OUTSIDE THE ORGANISM

By Z. ŽEMKOWA

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Work on transplantation of human uterus mucous at various periods of the menstrual cycle was carried on by Caffier (2), Cron and Gey(3), Traut (5), Hirsch and Johnes (4), Joshito Azumi (1). All these writers, however, confined themselves to a record of endometrium growth in cultures. No histological analysis of the growing elements has been done by any of them. Some were not even confident of the kind of tissue grown outside the organism. Galustian who studied the histotypic peculiarities of the uterine epithelium, has been the first to give a histological analysis of its transformations. According to this writer, the epithelium of the rabbit womb forms cavities of liquefaction in tissue cultures. Its growth proceeds according to two types: 1) that of extensive growth in the form of one-layer membranes and 2) of spreading over the surface of the explant (epithelization), leading to the formation of one-layer epithelium of various height. Explanting human decidual membrane at early stages of pregnancy, Ulesko-Stroganova (6) observed a growth in the shape of membranes which the author considered as endothelial.

The aim of the present work that had been carried out under the direction of Prof. N. G. Chlopin, was to investigate the peculiarities of growth and transformation suffered by the rabbit's uterine epithelium in the course of pregnancy. Explantation was practised by the method of a suspended drop. For the sowings interplacental areas of the uterine mucous of a rabbit were taken at various terms of pregnancy (6th, 11th, 18th, 23rd, 24th, 25th day) and at the *postpartum* period. The cultures were observed both *in vivo* and on fixed preparations, partly total, partly serial cuts, beginning with the first 24 hours and up to the 15th day of growth outside the organism. It should be noted that when cultivating rabbit endometrium at the various stages of pregnancy referred to above, we invariably obtained the same pictures of epithelium growth. In order to avoid possible reiteration, I shall give here only such data that are common for all stages of pregnancy, characterizing the growth and transformation of uterine epithelium.

In vitro the epithelium of the womb gives an extensive growth in the shape of one-layer membranes; there is epithelization of the surface of the explant. Over mica the membranes grow, as a rule, within the region of liquefaction cavities. Among the most typical features of the growth of uterine epithelium during pregnancy should be classed: first, its ability to form membranes consisting of polynuclear cells during the first days of explantation; secondly, the simultaneous

growth of poly- and mononuclear elements, observed at later stages of cultivation. On the second day of cultivation the epithelium lining the surface of the explant nd consisting of peculiar polynuclear giant cells described in my foregoing note forms membranes which also consist of polynuclear elements with clear-cut intracellular boundaries. The size of the polynuclear cells increases with the distance from the central bit on account of their spreading over the mica. Each cell often contains from 5 to 20 nuclei, and even more; their arrangement in the protoplasm varies greatly. The protoplasm is subject to vacuolization and may be subdivided into the endoplasm and the exoplasm. In the central regions of the membrane intracellular cytoplasmic connexions are occasionally observable. At the periphery where loosening is expressed, the epithelial cells stand at intervals, forming reticulate connexions by means of cytoplasmic processi. Somewhat later, on the seventh day upon explantation, mononuclear elements appear among the polynuclear cells. Dividing by way of mitosis, the mononuclear cells grow from the crypt epithelium which unlike the covering epithelium preserves during pregnancy its usual character, and pass over into the zone of growth in the form of fan-like currents. The mononuclear cells of the membrane show an appreciable polymorphism. In some of the cells the nuclei attain gigantic dimensions, while in others they are in the state of fragmentation. At later stages of cultivation studied by us the epithelial membranes did either preserve their mixed character with alternating prevalence of polynuclear or mononuclear elements, or else the polynuclear elements disappeared altogether.

In the case of epithelization of the explant the same typical distinctions between the epithelium of the crypts and that of the surface are manifest. The cells of the surface epithelium are gradually creeping over the muscles and connective tissue of the explant. They gradually flatten and transform into elongated flat elements, preserving their polynuclearity. Rising to the surface and covering the fragment, the cryptic epithelium contains mononuclear cells of various height; these often show mitoses which are not to be observed in giant elements.

At all terms of cultivation of the uterine mucous taken on the third day upon parturition, when the covering epithelium loses its polynuclear cells and comes back to its usual state, we observed the growth of epithelial membranes which consisted of mononuclear cells alone.

State Oncological Institute.
Leningrad.

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